COLLECTION AND ANALYSIS OF WEEKEND/WEEKDAY EMISSIONS ACTIVITY DATA IN THE SOUTH COAST AIR BASIN

ARB Contract Nos. 00-305 and 00-313

FINAL REPORT
STI-901140/901150-2477-FR

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May 7, 2004

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ACKNOWLEDGMENTS

The authors gratefully acknowledge the contributions of Leon Dolislager of the California Air Resources Board (ARB), the ARB technical contact and Project Officer; Population Research Systems of San Francisco, the firm that conducted surveys and recruited study volunteers; Wiltec, Inc. of Antioch, California, the firm that deployed surface street traffic counters; Caltrans for providing freeway weigh-in-motion data; GeoStats of Atlanta, Georgia, the firm that supplied the in-vehicle sensors (GeoLoggers) and performed initial data processing and quality assurance; the South Coast Air Quality Management District for providing continuous emissions monitoring systems data; and our colleagues at Sonoma Technology, Inc.

This report was submitted in fulfillment of ARB contract numbers 00-305 and 00-313, "Collection of Micro-Scale Emissions Activity Data in the South Coast Air Basin (WE/WD Micro-Scale)" and "Collection and Analysis of Weekend/Weekday Emissions Activity Data in the South Coast Air Basin (WE/WD Macro-Scale)", by Sonoma Technology, Inc. under the sponsorship of the California Air Resources Board. Work was completed with the submission of this report.

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ABSTRACT

This report summarizes the efforts undertaken by Sonoma Technology, Inc. (STI) on behalf of the California Air Resources Board (ARB) to characterize, by day of week, activities associated with emissions of air pollutants. Activity data were collected in the South Coast Air Basin (SoCAB) during summer 2002. Activity data are an underlying component of emission inventories. Emission inventories are needed for evaluating the effectiveness of emission control plans and as input to complex air quality models that characterize the impact of emissions on air quality. Air quality modeling, based on emission inventories, is a critical component of demonstrating that emission control measures in regulatory plans will meet ambient air quality standards established to protect public health and welfare.

In recent years, the ozone weekend effect, where ambient ozone concentrations tend to be higher on weekends than on weekdays in major urban areas, has been of particular interest. Although the trend of ozone concentrations in the SoCAB has been downward, the rate of decline has been faster on weekdays than on weekends, so much so that ozone concentrations on weekends now determine the "design value" for emission control plans. This ozone weekend effect is somewhat counter-intuitive because ambient concentrations (and presumably emissions) of ozone precursors decline on weekends compared to weekdays. Because peak ozone concentrations have historically occurred on weekdays, emission inventories were developed from activity factors characterizing average weekdays. If air quality models are to effectively guide emission control plans, it is now necessary to develop emission inventories representative of each day of the week, with particular focus on Saturday and Sunday activity patterns.

Some of the factors that can cause increased ground-level ozone concentrations in the SoCAB have been investigated by studying the differences in mobile and stationary source emission activity patterns that occur on weekdays and weekends. A variety of tools were used to characterize day-of-week and time-of-day activity patterns for major types of emissions sources in the SoCAB: (1) telephone and mail surveys; (2) installation of global positioning systems (GPS) in volunteers' cars; (3) measurements of traffic volumes at fixed locations; (4) acquisition of continuous emissions monitoring systems (CEMS) data for major point sources of NO_x; and (5) confirmation of emissions sources and activity patterns by in-neighborhood observers. The results show that activity levels generally decline on weekends (especially Sunday) relative to weekdays for (1) on-road mobile sources (about 10-25%, with larger, 50-75%, decreases for heavy-duty vehicles), (2) commercial off-road mobile sources (about 90-95%), and (3) commercial area sources (about 75-80%). In addition, NO_x emissions from point sources declined about 5-10% on weekends. In contrast, activity levels for recreational sources (e.g., barbecues and recreational vehicles [boats, ATVs]) increased about 25-165% on weekends relative to weekdays. As observed in previous analyses, not only does the amount of vehicular activity change but the timing also changes from a bimodal distribution associated with morning and afternoon commutes to work and school on workdays to a broad midday peak on weekends. New insights were gained from the instrumented light-duty-vehicle study: a high proportion, about 35%, of the highway vehicle miles traveled (VMT) occurred at speeds greater than 65 miles per hour and an apparent fewer number of trips per day were made than were counted in a previous study (about 2 less on both weekdays and weekends—4.7 vs. 6.7 on weekdays and 3.8 vs. 5.9 on weekends).

The results from this study will be used to refine summertime activity estimates and their associated emissions by time of day and day of week. Improved activity estimates will result in improved emission estimates and air quality modeling, which will help ensure that health-protective and cost-effective policies and plans are developed for controlling criteria pollutants and toxic air contaminants.

EXECUTIVE SUMMARY

ES.1 STATEMENT OF PROBLEM

Emission inventories are used to assess the effectiveness of emission control programs and to model the formation of secondary pollutants (e.g., ozone) whose concentrations are not directly proportional to the emission of precursors leading to its formation in the atmosphere. These inventories are currently based on average weekday emissions during the summer or winter. However, emissions also vary by day of week and time of day. These variations have ambient air quality implications. Proper characterization of the temporal, spatial, and compositional variations in emissions is important for the development of cost-effective and health-protective emission control regulations for criteria pollutants and toxic air contaminants. The increasing prevalence of higher ozone concentrations on weekends compared to weekdays necessitates the development of day-specific emission inventories with particular emphasis on improving the inventories for Saturdays and Sundays when activity and emission patterns differ significantly from weekdays. The purpose of this project was to collect and characterize pertinent activity data in the South Coast Air Basin (SoCAB) that could be used for improving current estimates of the temporal variations in emissions from important source categories. More accurate characterization of emissions will lead to more accurate modeling of air quality impacts and to more cost-effective and health-protective emission control regulations.

ES.2 BACKGROUND

The California Air Resources Board (ARB)-sponsored projects, "Collection and Analysis of Weekend/Weekday Activity Data in the South Coast Air Basin" and "Collection of Micro Scale Emissions Activity Data in the South Coast Air Basin" (ARB Contract Nos. 00-305 and 00-313) have been completed. These studies were initiated as a component of research into the "ozone weekend effect," a phenomenon characterized by ozone concentrations often greater on weekends than on weekdays in the SoCAB, in other areas of California, and in other cities in the United States. Because it is counter-intuitive that concentrations of secondary pollutants, such as ozone, could be higher despite lower concentrations of its precursors, it is important that environmental scientists and policymakers understand the cause(s) of this phenomenon. To effectively model, analyze, and understand the ozone weekend effect requires the development of emission inventories that better represent weekend conditions. Accurate day-of-week emission inventories can then be used to model air quality and help formulate effective and appropriate emission control strategies to achieve clean air. Thus, the primary objective of these studies was to collect and analyze day-specific and hourly data for emissions sources in the SoCAB (all of Orange County and portions of Los Angeles, Riverside, and San Bernardino counties). Attention focused primarily on mobile sources because this ubiquitous source type accounts for the majority of emissions for several pollutants and is likely to have the greatest influence on the ozone weekend effect and other air quality issues. A concurrent objective was to present the results, data, and recommendations in a manner that can be used in ARB's on-road, off-road, and stationary source emissions models and methodologies.

ES.3 STUDY DESIGN AND METHODS

The study design focused the majority of efforts on improving characterizations of on-road motor vehicle activities. The design also called for a significant effort to improve off-road mobile activity factors and lesser effort toward characterizing activities associated with stationary and area sources.

A variety of data gathering methods were used to characterize day-of-week activity patterns: (1) telephone and mail surveys of 870 households, 137 small businesses, and 258 construction businesses throughout the SoCAB; (2) in-vehicle sensors tracking the activities of 107 vehicles representing 68 households; (3) measurements of traffic volumes at dozens of fixed locations, including surface streets and freeways; (4) day-specific continuous emissions monitoring systems (CEMS) data for major point sources; and (5) field surveys with on-site technicians recording observations and noting differences in activities between weekdays and weekends.

ES.4 RESULTS

The results show that activity levels for on-road mobile sources, commercial off-road mobile sources, and commercial area sources declined on weekends relative to weekdays. In addition, NO_x emissions from point sources declined on weekends. In contrast, activity levels for recreational sources (e.g., barbecues and recreational vehicles) increased on weekends relative to weekdays. It seems most likely that these shifting activity patterns are due to variations in peoples' behavior as they follow their work-week and weekend habits.

A quantitative summary of the observed activities by emission source category and investigative method follows.

<u>On-Road Mobile Sources</u>

Based on surveys of over 800 households:

1. On average, there are 2.0 vehicles per household.
2. Fewer trips are taken on Sunday than on any other day of the week.
3. Trips are less likely to occur in the morning on weekends than on weekdays.

Based on position tracking of 107 vehicles from 68 households:

1. Daily vehicle miles traveled (VMT) is lower on Saturdays (0-10%) and Sundays (28-33%) than on weekdays. On a daily average, each vehicle was driven 28 miles on weekdays and 22 miles on weekends.
2. Highway travel accounts for about 60% of the daily VMT (57% on weekdays; 63% on weekends).
3. Traffic activity (number of vehicles) has a bimodal distribution, peaking at 0700-0800 and 1600-1700 PST on weekdays, and one broad peak from noon to 1700 PST on weekends.

4. A large proportion (about 35%) of the highway VMT occurs at speeds greater than 65 miles per hour.
5. The number of vehicle trips per day gradually increases from 4.8 to 5.6 from Monday to Friday but drops on weekends (4.1 on Saturday and 3.6 on Sunday).

Based on surface street traffic counts in 10 neighborhoods:

1. Traffic counts drop 20-33% from weekdays to weekends. The decline is much greater for heavy-duty vehicles (59-78%).
2. Traffic counts follow a bimodal distribution on weekdays but a broad single-mode distribution around midday on weekends.

Based on freeway traffic counts at 10 locations:

1. Total traffic counts generally follow a bimodal distribution on weekdays but a broad single-mode distribution around midday on weekends. Traffic counts of heavy-duty vehicles, however, generally follow a broad single-mode distribution around midday on all days of the week.
2. Daily total traffic counts are generally lower (about 11% on Saturdays and about 26% on Sundays) than on weekdays. However, traffic counts of heavy-duty vehicles generally declined 50-75% on weekends compared to weekdays.
3. Exceptions to the norm were observed at locations near recreational attractions and entry points to the SoCAB.

Off-Road Mobile and Area Sources

Based on survey data:

1. Some residential activities, such as barbecuing, boating, off-road driving, and painting, increase 25-165% from weekdays to weekends. Other residential activities associated with personal care and housekeeping varied by less than 25% during the seven-day week.
2. Business activity tends to decline about 60-90% on Saturdays compared to weekdays and almost ceases on Sundays. Exceptions include businesses that use gas ovens.

Point Sources

Based on continuous emissions monitoring systems (CEMS) data:

1. Total NO_x emissions decline about 5% on weekends compared to weekdays.
2. Facilities with smaller NO_x emissions tend to exhibit larger declines about 10% from weekday to weekend.

By expanding previous activity characterizations and confirming other recent studies, these results augment the robustness of, and confidence in using, these day-of-week activity factors to develop new day-specific emission inventories. Day-specific emission inventories are critical for assessing causes of the ozone weekend effect and for properly guiding future air pollution control strategies and plans.

ES.5 CONCLUSIONS AND RECOMMENDATIONS

This new data collected during this project promotes better characterization of activity patterns influencing ambient air quality. These results will be useful for refining emission inventories, improving air quality modeling performance, and understanding atmospheric processes, and defining how ambient air quality standards can be expeditiously met . Based on the results reported above, recommendations are presented for developing day-specific emission inventories:

- adjust daily activity levels and diurnal profiles for on-road mobile sources;
- alter modeled speed distribution profiles for on-road mobile sources;
- adjust portions of the inventory upward or downward depending on the associations of each inventory segment with recreational versus commercial activities; and
- forecast on weekends slightly lower emissions from point sources than on weekdays.

In addition, several areas of further research are recommended to refine and improve the emission inventory:

- investigate speed distributions and emission rates for vehicle speeds above 65 miles per hour;
- investigate spatial shifts in emissions-producing activities from weekdays to weekends; and
- investigate preferential choices of certain types of vehicles on weekdays versus weekends.

1. INTRODUCTION

This report presents the methods used and findings of the California Air Resources Board (ARB)-sponsored projects, “Collection and Analysis of Weekend/Weekday Activity Data in the South Coast Air Basin” and “Collection of Micro Scale Emissions Activity Data in the South Coast Air Basin” (ARB Contract Nos. 00-305 and 00-313). This study was initiated because, in recent years, concentrations of ozone—a product of complex photochemical reactions in the atmosphere—tended to be higher on weekends than on weekdays in some areas of California, while concentrations of directly emitted pollutants such as carbon monoxide (CO) and nitrogen oxides (NO_x) tended to be lower. This situation highlighted the need to develop and improve weekend-specific emission inventories—inventories that could support better predictions of the complex responses of atmospheric pollutants to differential emissions reductions and alternative control scenarios. In order to meet this need, the primary objectives of the study were to collect, process, and analyze day-specific, hourly activity data for stationary and mobile emissions sources in the South Coast Air Basin (SoCAB) counties (including Los Angeles, Riverside, San Bernardino, and Orange Counties). An additional objective was to present the results and data in a manner that will support ARB’s on-road, off-road, and stationary source emissions models and methodologies. Secondary benefits of this project include refined emission inventories for directly emitted pollutants and toxic air contaminants, which can be improved by applying more accurate and representative activity factors.

1.1 BACKGROUND

Emissions of primary (directly emitted) pollutants have declined in response to control measures as corroborated by their historically declining ambient concentrations (Alexis et al., 2002). However, ambient levels of secondary pollutants (which are formed in the atmosphere from physical and chemical reactions of precursor compounds) do not always decline proportionally with precursor concentrations. Since about 1990, for example, ozone concentrations in the SoCAB have tended to be higher on weekends than on weekdays (especially in the western SoCAB) despite assumed lower emissions on weekends than on weekdays (Fujita et al., 2003b; Fujita et al., 2003a; Chinkin et al., 2002; Glover and Brzezinski, 1998; Hsiao, 1999; Funk et al., 2001; Austin and Tran, 1999). This so-called “weekend effect”—observed mainly in urban areas of the United States, Canada, and the United Kingdom—has generated strong interest because the number of affected sites seems to be increasing and because it presents likely implications for ozone control strategies (Cleveland et al., 1974; Lebron, 1975; Graedel et al., 1977; Elkus and Wilson, 1977; Hoggan et al., 1989; Marr and Harley, 2002; Vukovich, 1998; Vukovich and Wayland, 1997; Diem, 2000; Raddatz and Cummine, 2001; Blanchard and Tanenbaum, 2003; Jenkin et al., 2002; Pun et al., 2003; Vukovich, 2000; Croes et al., 2003; Chinkin et al., 2003; California Air Resources Board, 2003b). Attempts to model the weekend ozone effect have relied on broad assumptions about changes in emissions-related activity on weekends. For example, the South Coast Air Quality Management District’s (SCAQMD) 1997 Air Quality Management Plan stated that “. . . information on [weekend] on-road travel patterns is not readily available. . . .” Therefore, sensitivity runs were made by assuming roughly a 50% reduction in heavy-duty vehicle (HDV) emissions to represent reduced commercial activity on weekends. Because of the contribution of on-road mobile sources to total emissions, special focus has been placed on assessing their day-of-week variations. Conventional thinking about travel activity patterns by day of week suggests a sharp decline in urban routes, moderate increases in main rural routes, and substantial increases in recreational access routes (Transportation Research Board, 1998). Additional efforts to assess travel activity in the SoCAB are nearing completion by the California Department of Transportation (Caltrans) and the South Coast Association of Governments (SCAG).

Much of the difficulty in addressing the ozone problem is related to ozone's complex photochemistry. The rate of ozone production is a non-linear function of the mixture of volatile organic compounds (VOCs) and oxides of nitrogen (NO_x) in the atmosphere. Depending on the relative concentrations of VOC and NO_x and the specific mix of VOC present, the rate of ozone formation can be most sensitive to changes in VOC alone, to changes in NO_x alone, or to simultaneous changes in both VOC and NO_x. Results of previous studies in the SoCAB indicate that, in general, air quality on weekends differs significantly from that on weekdays, and this difference is not due to weather phenomena. Therefore, it has been postulated that the observed weekend effect in the SoCAB arises from day-of-week variations in the temporal and spatial patterns of anthropogenic VOC and NO_x emissions, coupled with complex physical and chemical processes.

In fact, everyday observations and common sense suggest that aggregate variations in human activities, which follow a weekday-weekend (WD-WE) pattern, likely cause observable differences in air quality. Because most ozone precursor emission inventories developed for use in assessing emission control strategies are intended to represent average weekday activity patterns, there is a general absence of detailed information about emission activity patterns and, thus, emissions, on weekends. Thus, the intent of this project is to address these needs by investigating day-of-week differences in emission activity levels and ozone precursor emission rates.

1.2 SUMMARY OF METHODS

We applied a variety of methods to directly observe and characterize WD-WE activity levels and diurnal profiles for on-road mobile sources, off-road mobile sources, area sources, and point sources. Because mobile sources were considered to be of such importance, the majority of our efforts were focused in this area. The data collection methods we applied included the following elements.

- *Telephone and mail surveys.* Surveys of 870 households, 137 small businesses, and 258 construction businesses throughout the SoCAB were used to develop activity data sets for on-road mobile sources, off-road mobile sources (including recreational and commercial equipment), and area sources.
- *In-vehicle sensors.* A total of 107 vehicles, from 68 households throughout the SoCAB, were recruited to participate in an in-vehicle sensor study. GeoLoggers—global positioning system (GPS) receivers with data loggers—were installed in participants' vehicles for 10-day or longer periods and recorded time-activity data at 5-second intervals, including vehicle position and speed. Results included distributions of travel

activities for the volunteer group by day of week, hour of day, vehicle type, and road class.

- *Observations of traffic volumes at fixed locations.* Traffic counters were deployed in 10 neighborhoods of the SoCAB to record traffic volumes and vehicle types in 15-minute increments. In addition, we acquired data from Caltrans weigh-in-motion (WIM) sensors, which record traffic volumes by vehicle type at numerous freeway locations throughout SoCAB.
- *Acquisition of day-specific continuous emissions monitoring systems (CEMS) data for point sources.* CEMS data for May-October of 2002 were provided by the SCAQMD for 84 unique facilities in Los Angeles County and the surrounding counties of Orange, Riverside, and San Bernardino. These data included highly time-resolved and facility-specific NO_x emissions rates.
- *Field surveys.* Throughout the summer, a technician visited five neighborhoods of interest in the SoCAB to perform ground-truth (verification) surveys. The technician recorded observations of the surroundings on weekdays and weekends and prepared detailed land use/land cover maps for these neighborhoods (Appendix A). The technicians recorded observations of reduced traffic activities, reduced commercial activities, and increased recreational and residential activities on weekend mornings relative to weekday mornings. Although these observations are only qualitative assessments, they corroborate the general tendency of quantitative measurements presented in Sections 2 and 3.

1.3 SUMMARY OF KEY FINDINGS

In brief, key findings of this study are that activity levels for on-road mobile sources, commercial off-road mobiles sources, and commercial area sources decline on weekends relative to weekdays. In addition, NO_x emissions from point sources were observed to decline on weekends. In contrast, activity levels for recreational off-road mobile sources and recreational area sources increase on weekends relative to weekdays. Common sense would indicate that these shifts, and shifts in the diurnal patterns for on-road mobile sources and recreational sources, are clearly due to variations in peoples' behavior as they follow their work-week and weekend habits. Some unexpected findings that are also likely to be related to work-week and weekend habits are (1) substantial accrual of vehicle miles of travel (VMT) at vehicle speeds above 65 miles per hour, especially on weekends, (2) predominance of travel on major highways, especially on weekends, (3) possible preferential selection of light-duty utility vehicles over passenger vehicles for weekend travel, and (4) shifts in activities from central urban locations towards outlying and recreational areas on weekends.

1.4 COMPARISON TO OTHER RECENTLY COMPLETED STUDIES

In addition to the literature sources listed in Appendix B, the results of several recently completed projects may be compared with the findings of this study.

- NuStats (2002) observed similar rates of vehicle ownership (1.8 vehicles per household) and household occupancy (3.0 persons per household) in the SCAG region. In addition, NuStats observed a median household income in the SCAG region ($31,242) that was consistent with that found during this study (≤ $50,000). Lastly, NuStats observed a number of trips per vehicle per day (4.6 per day) that was within 10% of the number of soaks per vehicle per day observed during this study (5.1 per day).

- Magbuhat and Long (1996) reported the following observations for a study conducted in the SoCAB involving 7 vehicles that were loaned to 96 participants for periods of 7 days or longer. On average, vehicles were started 6.7 times per day, driven 46 miles per day, and driven at an average speed of 43 miles per hour. In addition, vehicles were taken on 7.1 trips on the average weekday and 5.9 trips on the average weekend day.

  In contrast, the findings reported in Section 2 reflect significantly lower levels of vehicle activity. Vehicles had 4.73 soaks per day,[1] were driven 26 miles per day, and were driven at an average speed of 40 miles per hour. In addition, vehicles had 5.1 soaks on the average weekday and 3.8 soaks on the average weekend day.

  One possible reason for the differences is that participants in the Magbuhat and Long study received loaner vehicles equipped with in-vehicle sensors. It is possible that participants preferentially used the loaner vehicles rather than their own vehicles, or that they used the loaner vehicles to a greater extent than they would have used their own vehicles.

- Battelle Memorial Institute (1999) observed greatly reduced numbers of starts by heavy-duty trucks on weekends when compared to weekdays during a California study that involved 140 trucks outfitted with GPS. In addition, they observed single-mode distributions in the frequencies of starts. These observations are consistent with the heavy-duty vehicle volumes that are reported in Section 2, which are reduced on weekends and follow single-mode distributions.

Results from the Caltrans/ARB Modeling Program (CAMP) were not available in time for evaluation and comparison. The purpose of CAMP is to collect travel activity data across four metropolitan regions in California, and to use that data to develop facility-specific speed correction factors (SCFs) for use with EMFAC 2000.

[1] Starts were not detected directly, but may be considered approximately equal to the estimated number of soaks if key-on/key-off events without detectable travel are assumed to be negligible.

2. ON-ROAD MOBILE SOURCES

For 2002, on-road mobile sources were estimated to contribute the largest quantities of ozone precursor emissions in the SoCAB, accounting for about 42% of average daily reactive organic gas (ROG) emissions and 59% of average daily NO_x emissions (California Air Resources Board, 2003a). In addition, the transportation planning community generally acknowledges that weekday/weekend traffic patterns differ substantially. These two factors make on-road sources the primary focus of this study.

2.1 OVERVIEW OF METHODS

Four approaches were employed to collect data for on-road mobile sources. The first two methods focused on the activity patterns of individual vehicles, while the third and fourth methods focused on observations of traffic volumes at fixed locations. Each method is briefly described as follows:

1. Over 800 households throughout the SoCAB were surveyed by telephone and mail to collect information related to household vehicles and their usage.
2. A subset (68) of the surveyed households voluntarily participated in an instrumented vehicle study, which entailed the installation of instruments, GeoLoggers, in all household vehicles for 10-day or longer periods. One hundred and seven vehicles were included in the GeoLogger study group.
3. Traffic-volume and vehicle-type sensors were deployed for 10-day periods on surface streets at 30 fixed sites throughout the SoCAB.
4. WIM sensor data, which record traffic volumes by vehicle type at numerous freeway locations throughout the SoCAB, were acquired from Caltrans.

The remainder of this section provides further details about these methods and presents results, discussion, and conclusions for on-road mobile activity data.

2.2 INDIVIDUALS' ACTIVITY PATTERNS

2.2.1 Telephone and Mail Surveys

During summer 2002, we surveyed Los Angeles residents about the frequencies and timing of various emission-related activities, including the ownership and use of on-road motor vehicles. Partly to corroborate previous work (Chinkin et al., 2002), some of the surveys targeted five specific neighborhoods in the SoCAB in the immediate vicinity of air quality monitoring sites (Azusa, Burbank, Los Angeles North Main, Lynwood, and Rubidoux), while the remainder of the surveys were administered to randomly selected samples of residents throughout the SoCAB (**Figure 2-1**).

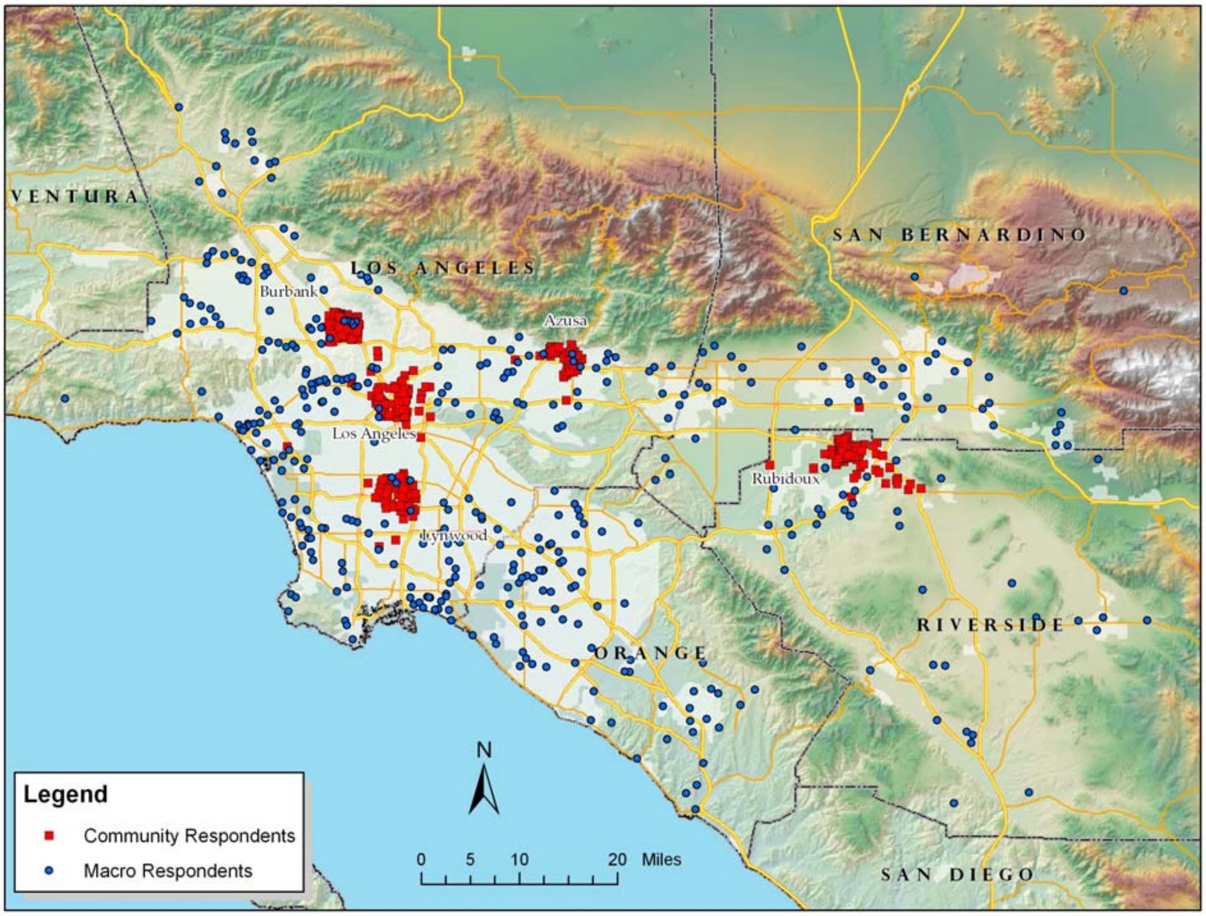


Figure 2-1. Locations of households that participated in the telephone and mail surveys.[2]

Data collection proceeded via telephone and mail surveys (which are described further in Section 3 of this report and reproduced in Appendix C). Participants responded by telephone to questions about the numbers and types of vehicles owned by household members. Then, during the mail portion of the survey, participants completed one postcard per day for 10 days and reported the frequencies and timings (morning, afternoon, or evening) of departures of passenger vehicles from their household.

Telephone survey results showed that, on average, participating households owned 2.0 vehicles. In addition, the number of times and times of day that vehicles departed from participants' households varied somewhat by day of week (see **Figures 2-2 and 2-3**). Differences between Sundays and weekdays were more noticeable than the differences between Saturdays and weekdays. On Sundays, zero or one departures were reported more frequently than on any other day. In addition, vehicle departures on weekends were more likely to be reported as occurring in the afternoons and less likely in the mornings than they were on weekdays. (However, it should be noted that "morning", "afternoon", and "evening" were

[2] "Community Respondents" resided in five specific neighborhoods near air quality monitoring sites. "Macro Respondents" were randomly distributed throughout the population of the SoCAB.

subjectively defined by the survey participants. Therefore, the survey results are only qualitative and inexact assessments. This simplification was necessary due to the succinctness of the postcard-style questionnaires.) These findings corroborate—at least directionally—the temporal profiles and the soak frequencies that were observed with surface street traffic counters, freeway WIM sites, and in-vehicle GeoLoggers.

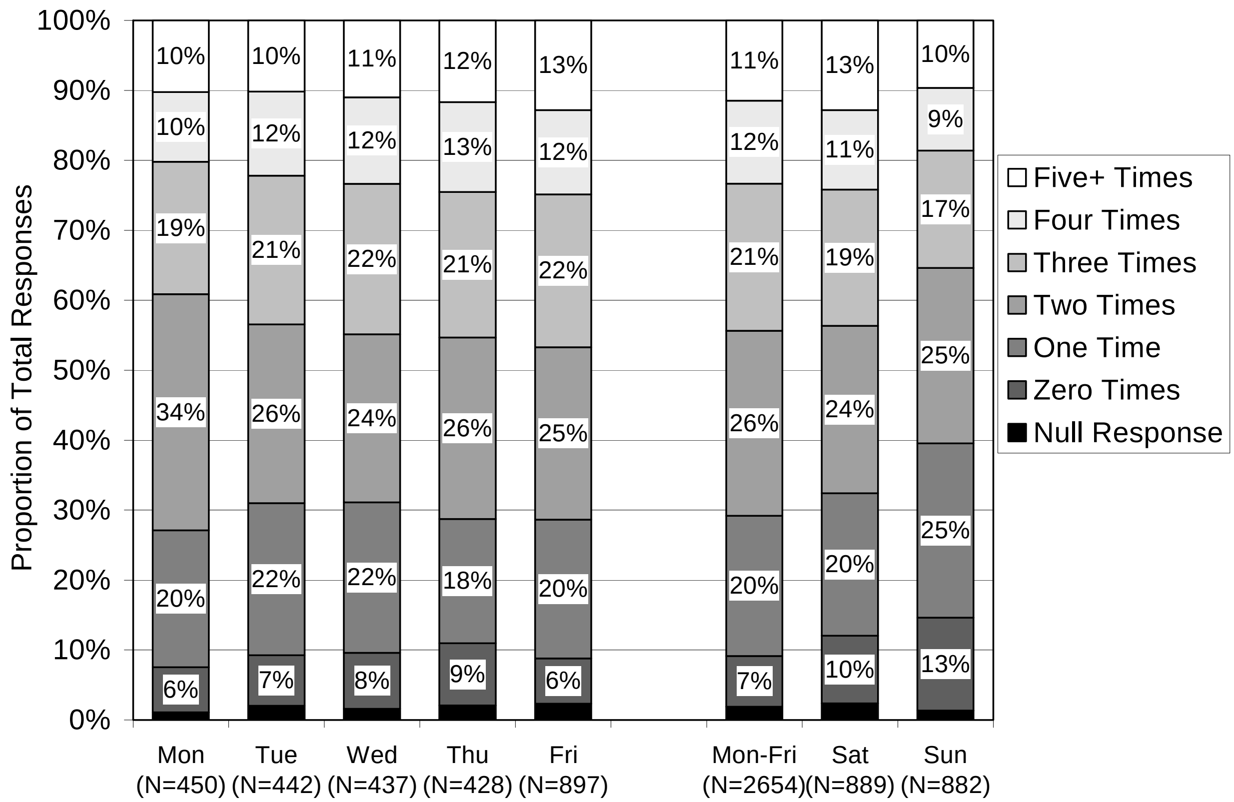


Figure 2-2. Proportion of vehicle departures per household by day of the week.

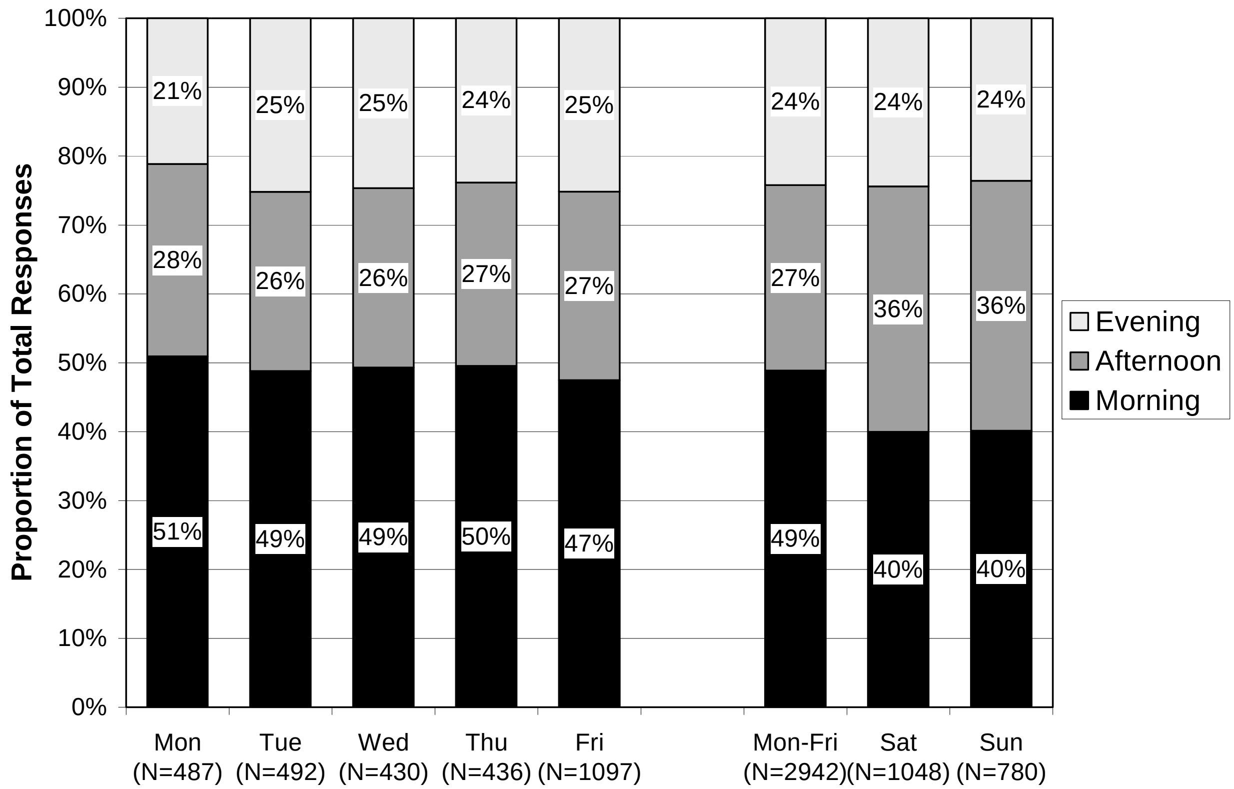


Figure 2-3. Proportion of vehicle departures by time of day. [3]

2.2.2 In-Vehicle Sensors (GeoLoggers)

A subset of households from the telephone and mail survey respondents was recruited to participate in an instrumented vehicle study (**Figure 2-4**). These participants volunteered to permit the installation of in-vehicle instruments—GPS receivers with data loggers, called GeoLoggers (**Figure 2-5**)—that would track the activities of all household vehicles for 10- to 15-day periods. Sixty-eight households and 107 vehicles participated in this portion of the study. The GeoLoggers recorded time-activity data at 5-second intervals, including vehicle position and speed.

[3] Note that "morning", "afternoon", and "evening" were defined subjectively by the survey participants. Therefore, the survey results are only qualitative and inexact assessments. This simplification was necessary due to the succinctness of the postcard-style questionnaires.

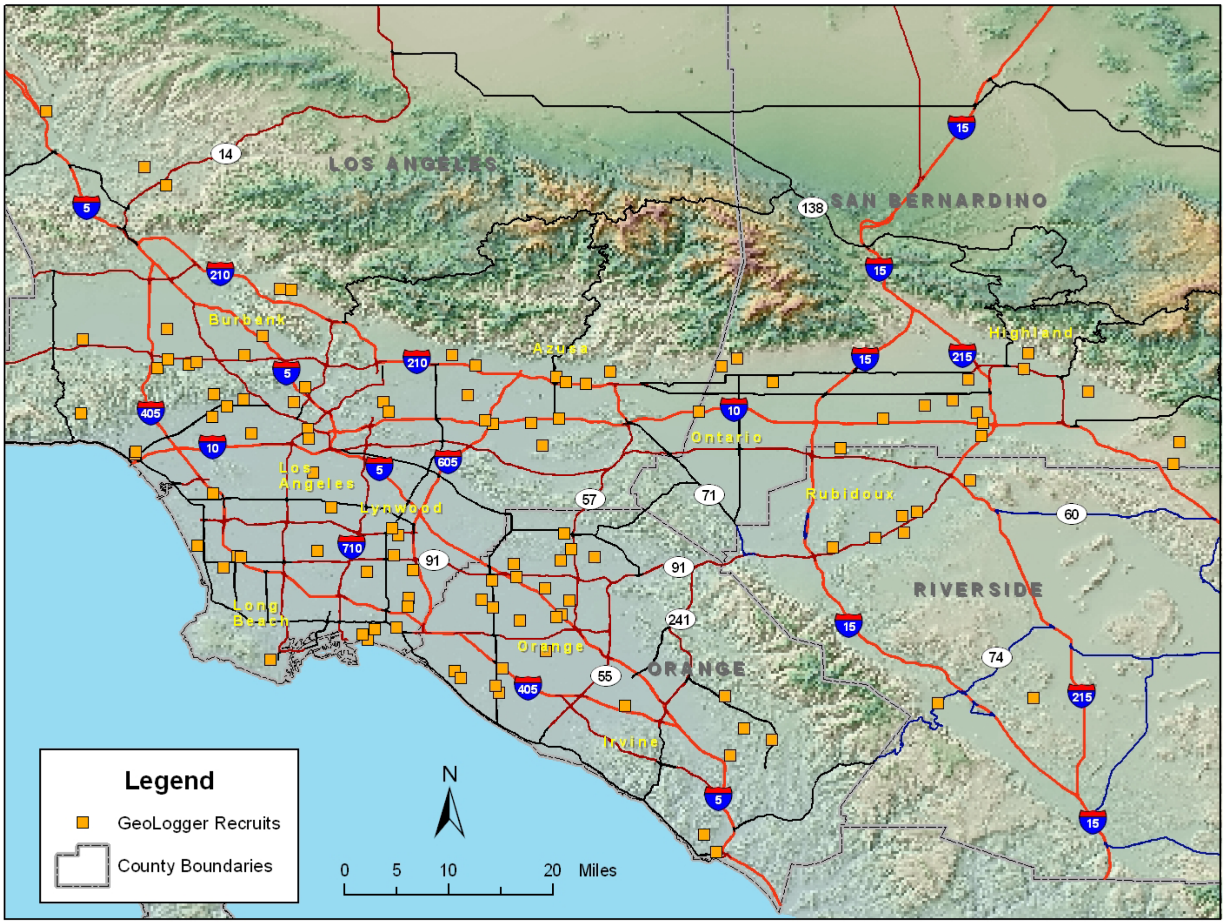


Figure 2-4. Locations of households that participated with the GeoLogger study.

Figure 2-5. The GeoStats GeoLogger.

GeoLogger data were downloaded by field technicians at the conclusion of each household's data collection period and transmitted to our subcontractor, GeoStats. GeoStats translated the individual vehicle data into desirable formats, identified potentially bad data points, and generated aggregated summary sets of vehicle activity data (e.g., trip length, average speed). The final GPS database received from GeoStats contained over 800,000 raw data points. With GIS, these data points were overlaid on a GPS-accurate street map of functional road classes (see **Figure 2-6**). Each data point was then matched to a road link and assigned to the functional class of that road link. A variety of results may be extracted from these databases, including distributions of travel activities for the volunteer group by day of week, hour of day, vehicle type, and road class.

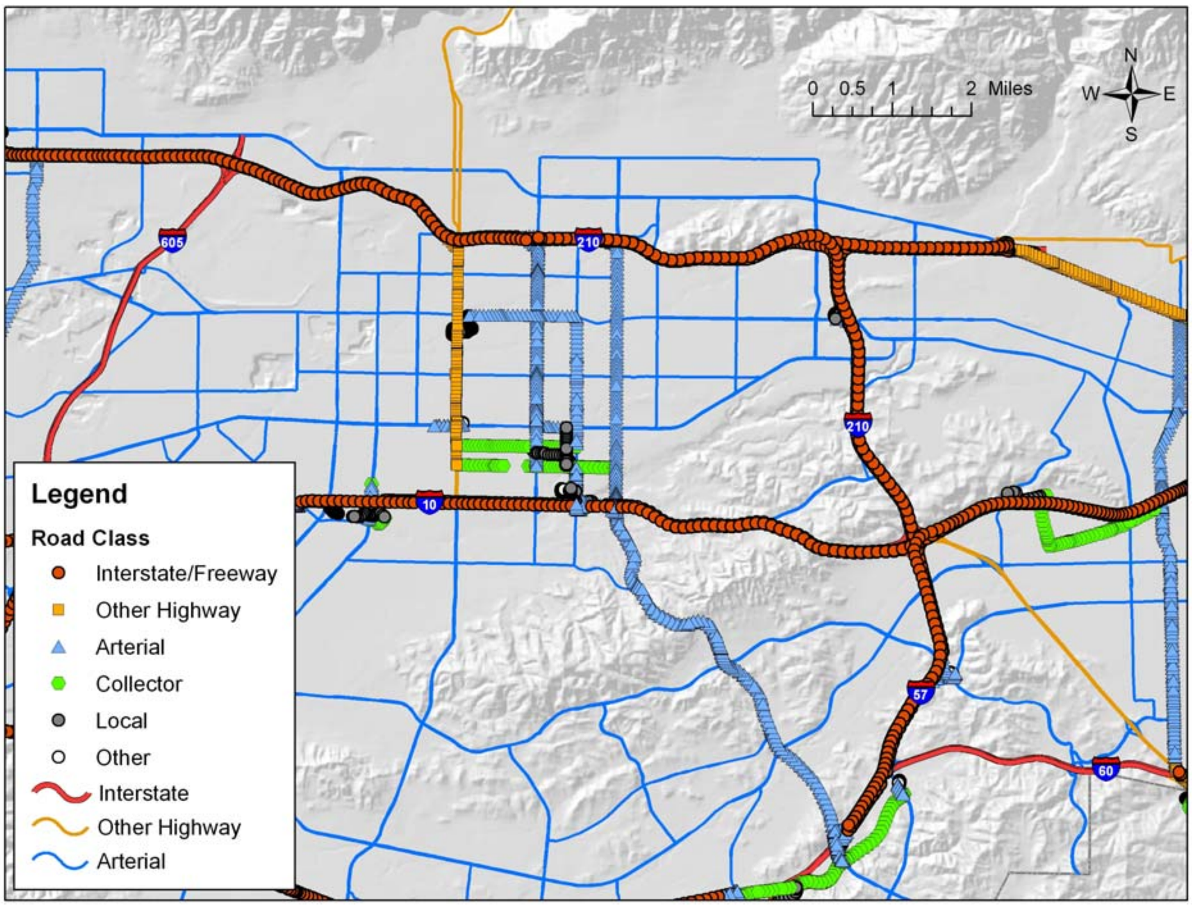


Figure 2-6. Raw data points from in-vehicle GeoLoggers matched to the road network.

Average VMT for each day of the week was calculated as shown in **Exhibit 2-1**. Results are displayed in **Figure 2-7**. VMT ranged from a low of 26 miles per vehicle (Monday) to a high of 29 miles per vehicle (Tuesday and Friday). The average VMT per vehicle on weekdays was about 40% higher than the average VMT on Sundays (28 vs. 20), and the average VMT on Saturdays was about 25% higher (25 vs. 20).

Day-of-week vehicle-specific average VMT (VMT_{ijm}) was calculated as the sum of VMT for each valid date of travel by each vehicle divided by the number of days (Equation 1). Day-of-week group-average VMT (VMT_m) was then calculated as the average of the day-of-week vehicle VMTs for all vehicles (Equation 2).

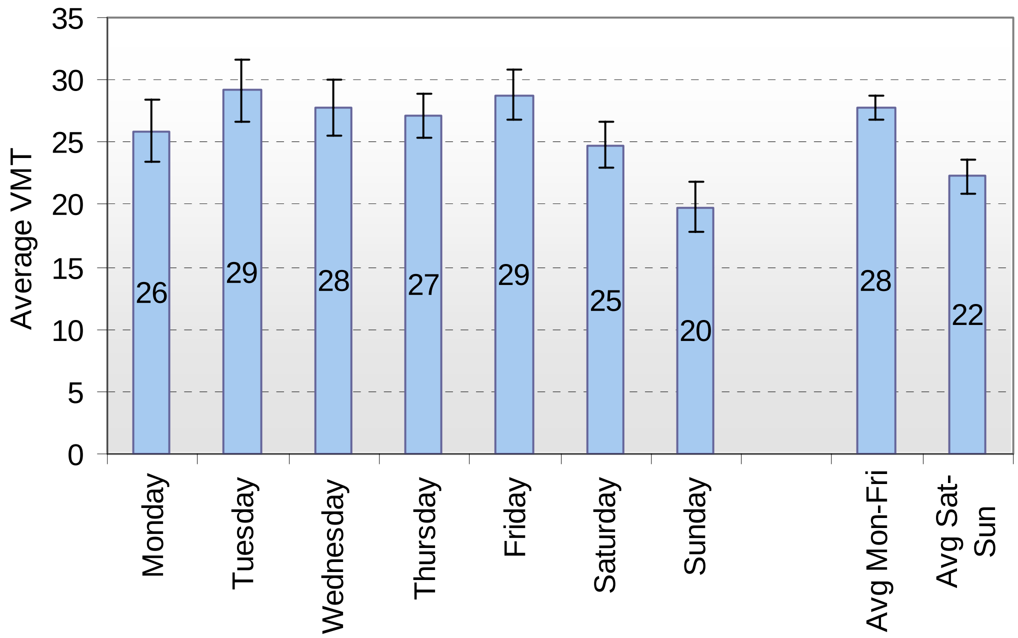
Day-of-week vehicle VMT: $$VMT_{ijm} = \frac{1}{n}\sum_{k} \mathrm{VMT}_{ijkm} \quad \textbf{(2-1)}$$

Day-of-week average VMT: $$VMT_{m} = \frac{1}{n}\sum_{ij} \mathrm{VMT}_{ijm} \quad \textbf{(2-2)}$$

where

i	=	household
j	=	vehicle (ij identify a unique vehicle)
k	=	valid date
m	=	day of week (e.g., Sunday, Monday, Tuesday, etc.)
VMT	=	vehicle miles traveled

Exhibit 2-1. Procedure to calculate average VMT.



(Error bars represent ±1 standard error of the mean.)

Figure 2-7. Average daily VMT per vehicle.

Weekly mileage accumulations for the vehicles participating in this study followed the lognormal distribution illustrated in **Figure 2-8**. Because the distribution was lognormal, a small number of vehicles driven far more than the average exerted a proportionately large influence on the arithmetic averages displayed in Figure 2-7. In fact, the 25 vehicles with the highest weekly mileage accumulations were associated with approximately 50% of VMT for all vehicles participating in the study. In order to investigate the potential effects of high-mileage vehicles on the averages, each vehicle's daily average VMT was normalized to its weekly total mileage accumulation. Then, the day-of-week activity pattern was recalculated as shown in **Figure 2-9** so that each vehicle bore equal influence on the day-of-week activity pattern. Increases in the activity levels on Friday and reductions to activity levels on Sunday (relative to the weekly average) are even more prominent in the normalized averages (Figure 2-9) than in the arithmetic averages (Figure 2-7). This phenomenon occurs because the high-mileage vehicles tended to exhibit a different average weekly driving pattern than all other vehicles as shown in **Figure 2-10**. High-mileage vehicles were driven 55-64 miles per day Monday through Friday (on average). Their activity levels on weekends declined by 22% from their weekday levels. All other vehicles were driven 16-18 miles per day Monday through Friday (on average). Their activity levels remained steady on Saturdays, but declined by 33%on Sundays.

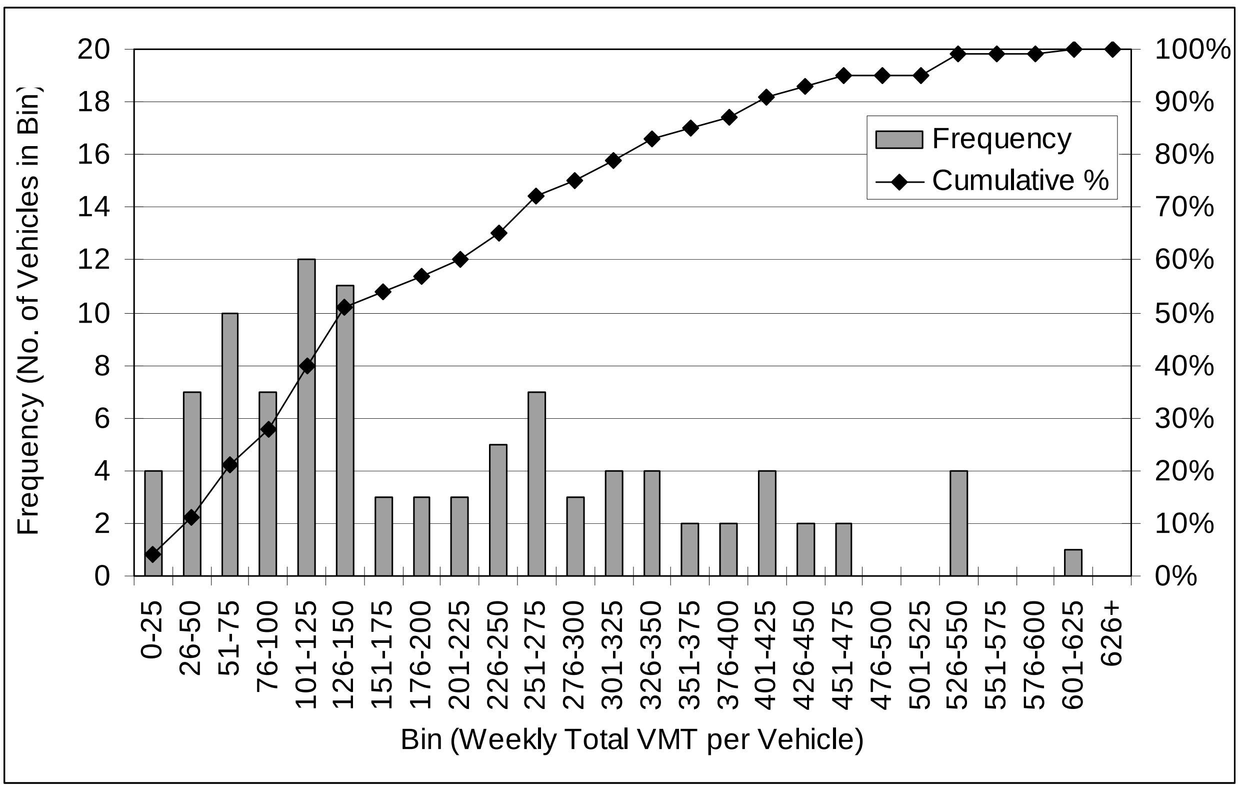


Figure 2-8. Frequency distribution of weekly mileage accumulations.

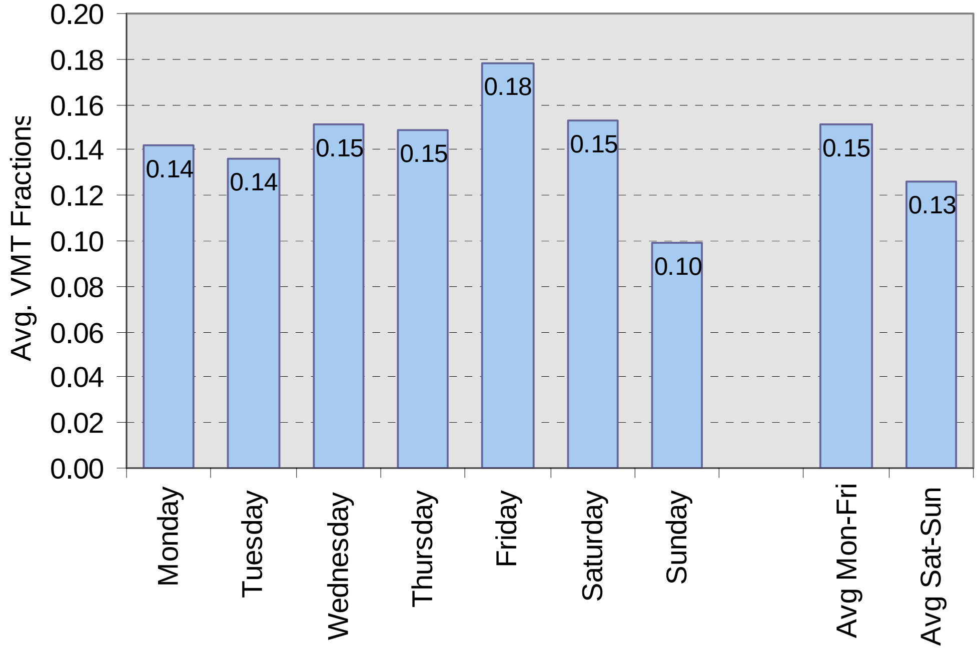


Figure 2-9. Normalized daily VMT per vehicle.

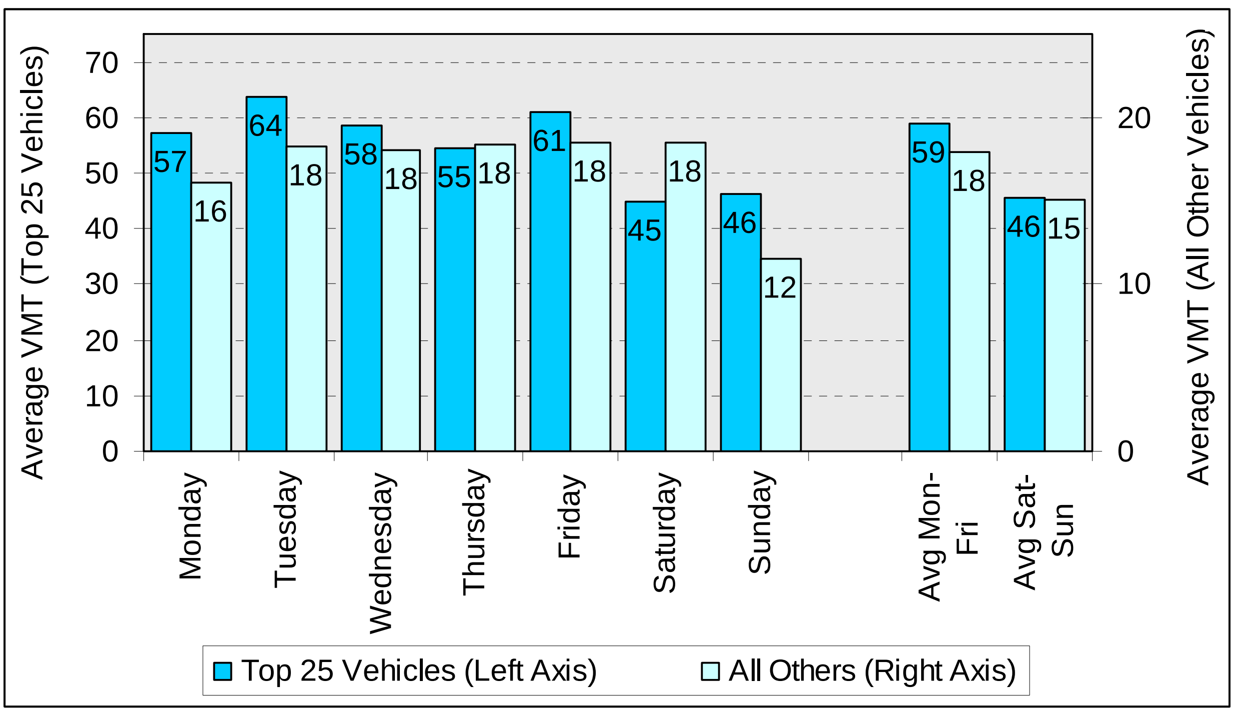


Figure 2-10. Average daily VMT per vehicle for the top 25 high-mileage vehicles (left axis) and all other vehicles (right axis).

Vehicle activity was further analyzed by vehicle type and functional road classes. **Figure 2-11** shows differences in daily activity levels for the 65 passenger cars and 42 light-duty utility vehicles that participated in the study. (Light-duty utility vehicles included sport-utility vehicles, minivans, and pickup trucks.) Vehicle type appeared to cause little difference in the five-day, Monday-Friday average and the two-day, Saturday-Sunday average. However, drivers' choices of vehicle type may vary during the week, that is, passenger vehicles may be preferred during the early part of the week (Sunday through Wednesday), while light-duty utility vehicles may be preferred during the later part of the week (Thursday through Saturday). **Figure 2-12** shows that the largest proportions of VMT occur on major highways throughout the week. However, on weekends, major highways account for a higher fraction of total VMT than on weekdays.

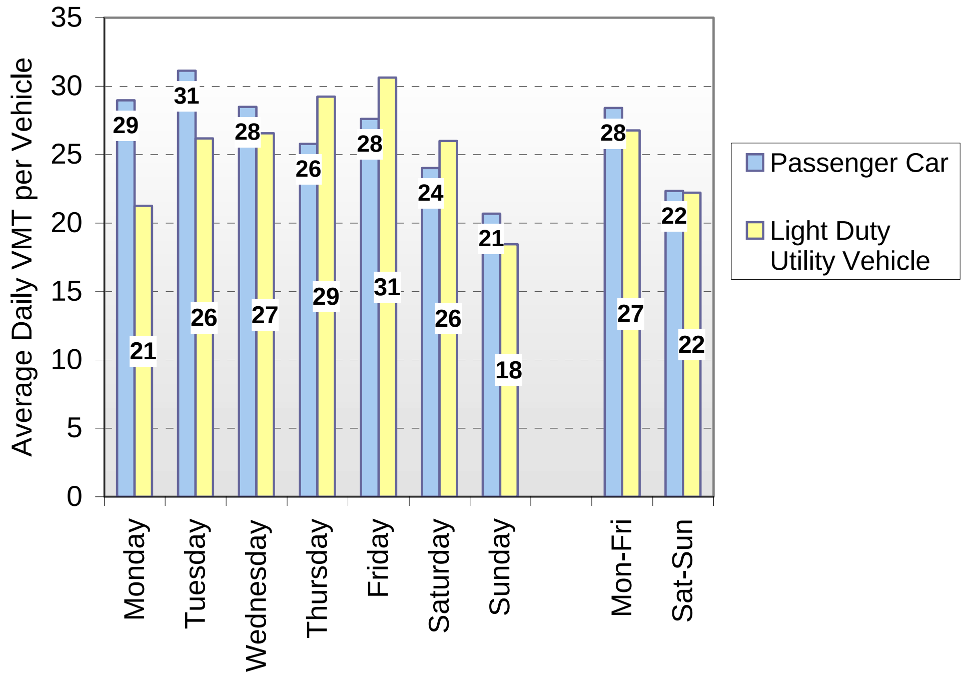


Figure 2-11. Average daily VMT per vehicle by vehicle type.

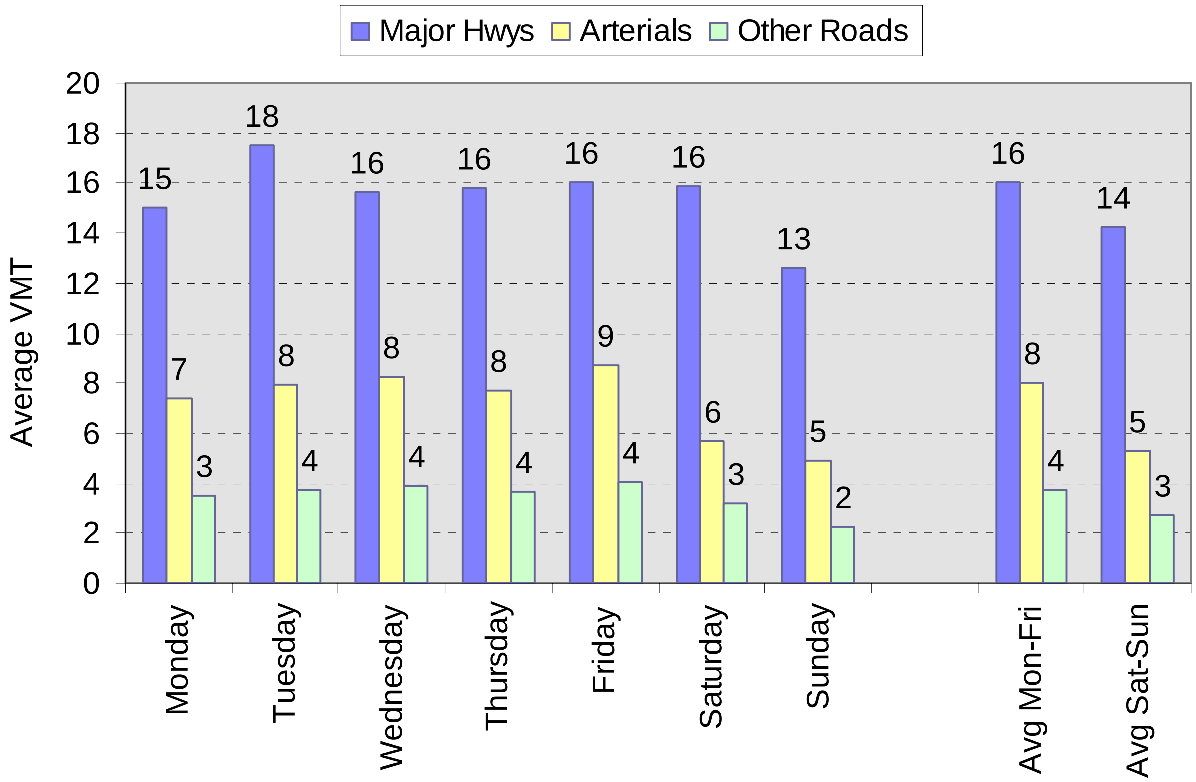
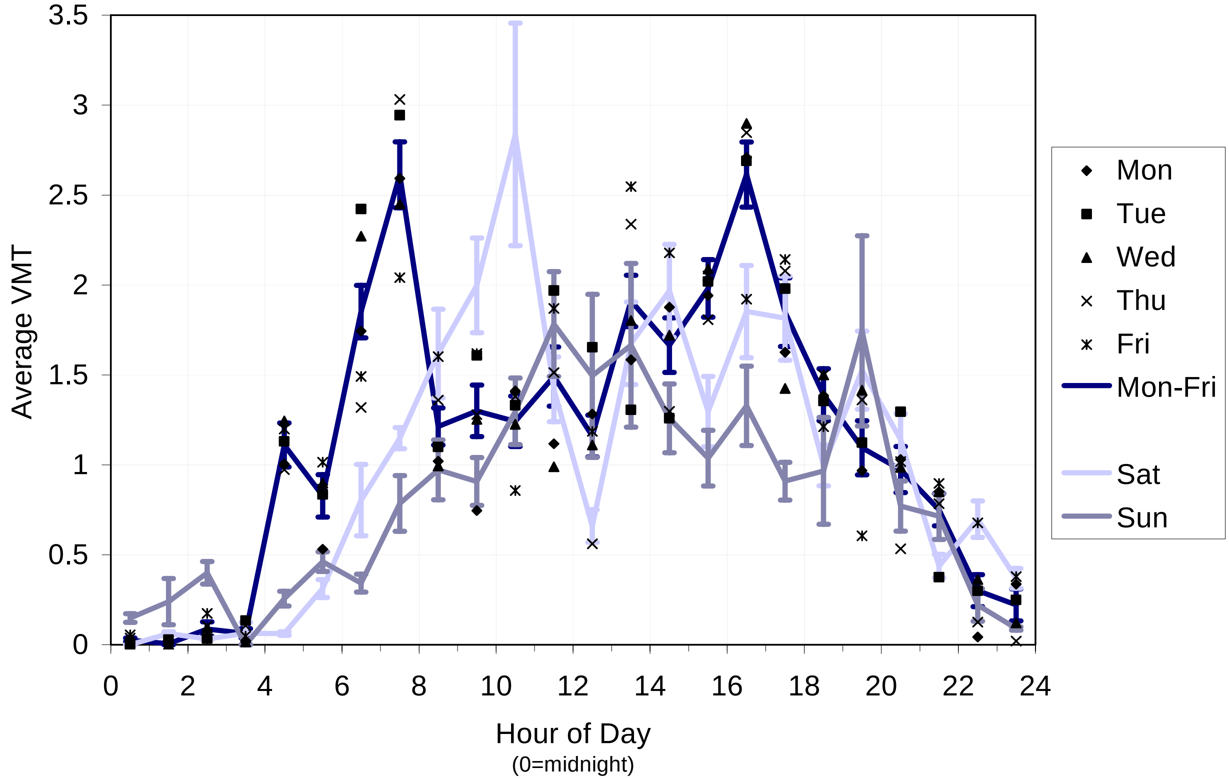


Figure 2-12. Average daily VMT per vehicle by road type.

The average hourly proportions of each vehicle's daily VMT were calculated and averaged for weekdays and for weekends (**Figure 2-13**). Although the data become variable when separated into hourly bins, one can discern the morning and afternoon peak travel periods at 0700-0800 and 1600-1700 PST on weekdays.



(Error bars represent ±1 standard error of the mean.)

Figure 2-13. Average hourly VMT per vehicle.

Investigation of speed distributions shows that 28% of travel on weekdays and 42% of travel on weekends occurred at speeds greater than 65 miles per hour (see **Figure 2-14**). That mobile source emissions models apply speed correction factors that do not account for vehicle speeds above 65 miles per hour may be a significant weakness in emission inventories for on-road mobile sources. **Figure 2-15** shows the speed distributions included in the EMFAC 2000 model. For comparison, we prepared speed distribution profiles for the peak travel periods from the GeoLogger data (see **Figure 2-16**). Results indicated that even during the peak travel periods, large proportions of VMT occur at higher-than-modeled vehicle speeds.

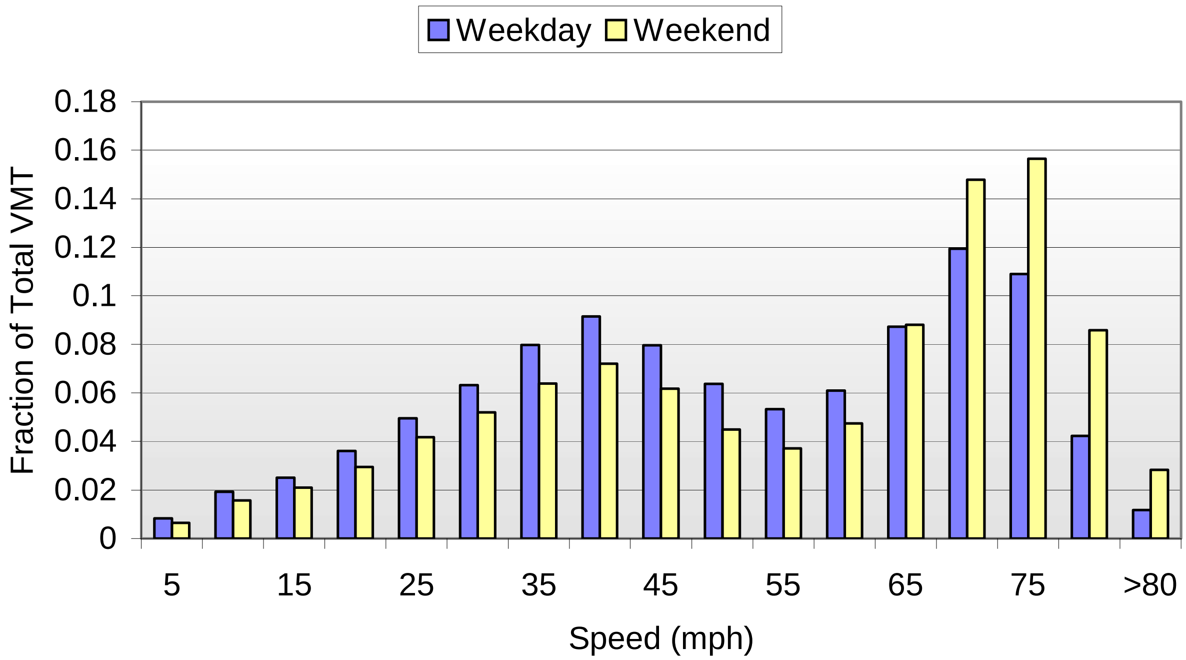


Figure 2-14. Average distribution of daily VMT by speed.

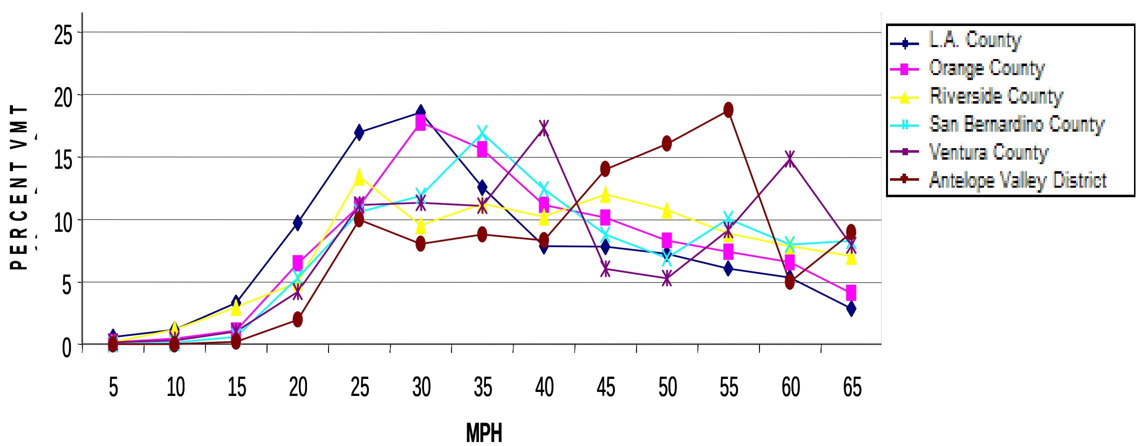


Figure 2-15. Modeled speed distribution of light-duty vehicles for the morning peak travel period (EMFAC 2000), 0700 to 0900. Source: EMFAC 2000 Technical Documentation.

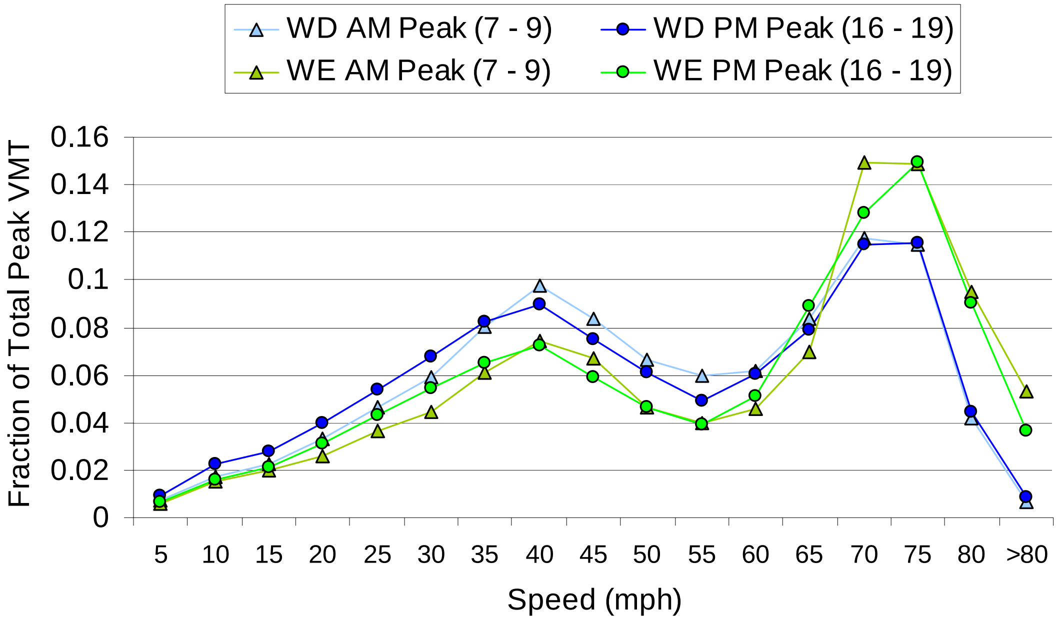
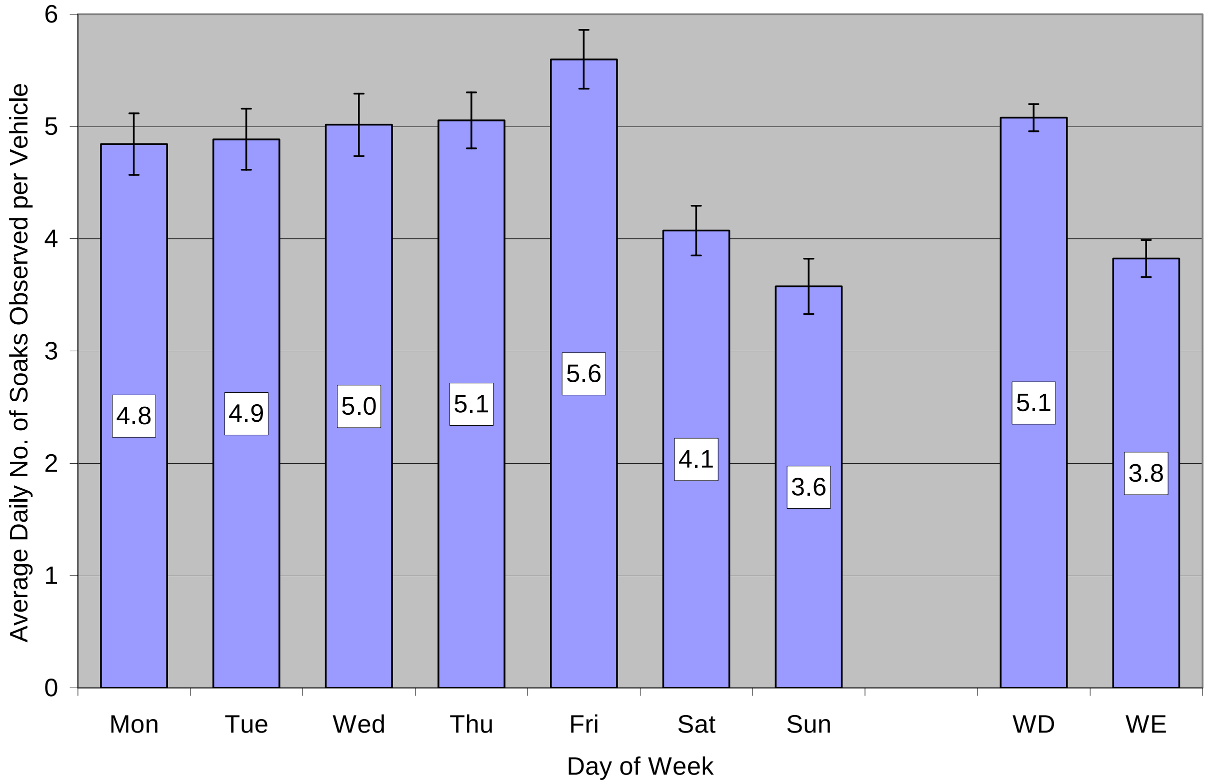


Figure 2-16. Observed speed distributions for the morning (0700 to 0900) and afternoon (1600 to 1900) peak travel periods.

EMFAC 2000 models the number of starts per day as a function that declines with vehicle age, from 6.56 starts per day at age 1 year to 3.72 starts per day at age 45 years (California Air Resources Board, 2003a). This range is reasonably consistent with the average number of soaks per day per vehicle that were observed among the GeoLogger study participants: from 3.6 to 5.6 soaks per day. However, EMFAC 2000 estimates a higher frequency of starts, 6.4 per day, than that observed for vehicles of age 7.5 years (the average age of our participating group of vehicles). The frequency of soaks varied by day of week as shown in **Figure 2-17**. The frequency of soaks remained fairly constant from Monday through Thursday, increased on Friday, dropped on Saturday, and dropped further on Sunday.

2.3 OBSERVATIONS AT FIXED LOCATIONS

We collected traffic data in 10 neighborhoods for 9- to 10-day periods and acquired traffic count data from Caltrans, which operates an extensive network of WIM detectors across the SoCAB's freeway system. These data were analyzed to characterize WD-WE differences in day-of-week and time-of-day traffic patterns.



(Error bars represent ±1 standard error of the mean.)

Figure 2-17. Average daily number of soaks per vehicle.

2.3.1 Surface Streets

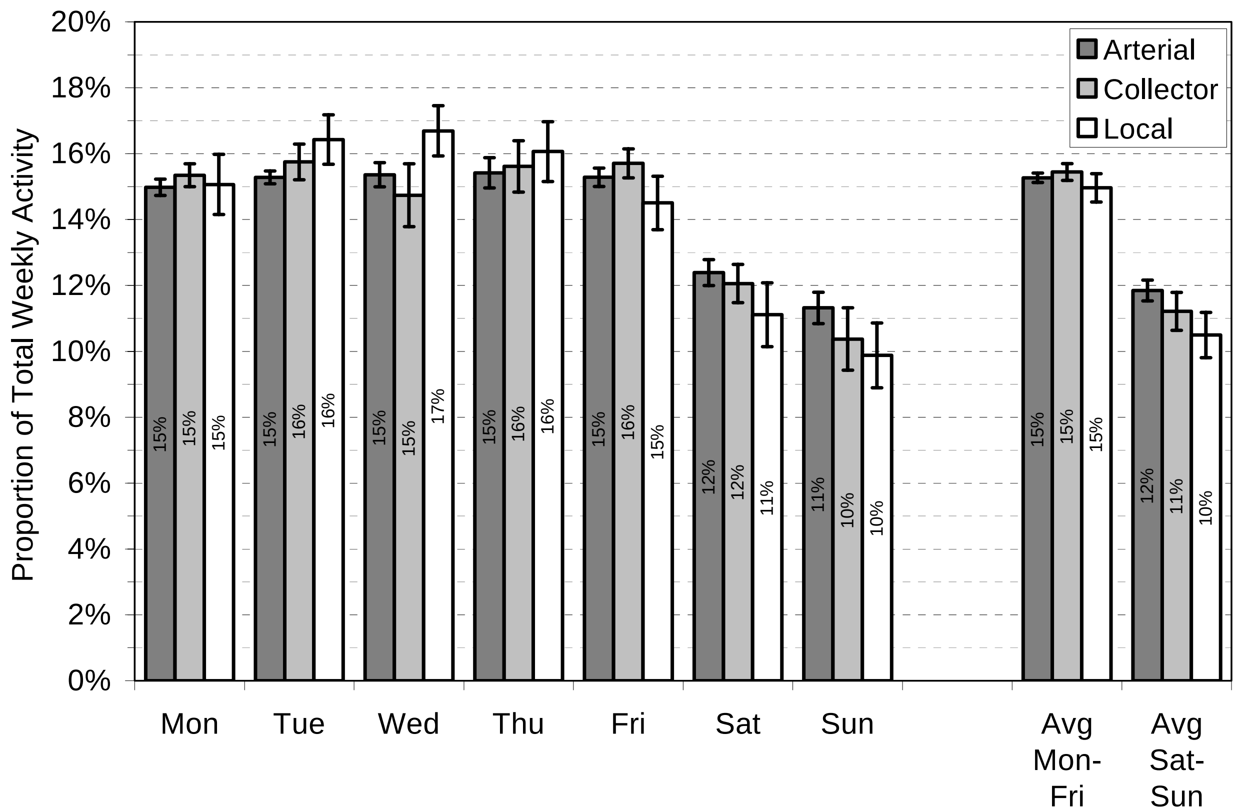
Traffic volumes were monitored on surface streets with automated pneumatic devices (loop sensors) that detect tire passages. If two loop sensors are placed in a lane with a known distance between them, they may be used to disaggregate traffic volumes by vehicle type. The vehicle typing is performed via an algorithm that processes time intervals between tire passages, and from these time intervals the algorithm predicts the number of axles, axle spacing, and vehicle type. The algorithm is associated with significant vehicle misclassification errors (much more so than WIM sites); however, these errors tend to cancel out when relative vehicle type counts are considered (e.g., number of trucks per day divided by the number of trucks per week).

Loop sensors were deployed at 10 neighborhoods throughout the SoCAB (see **Figure 2-18**). These neighborhoods included the five neighborhoods that were targeted for telephone and mail surveys (see Section 2.2, Section 3, and Appendix A), including Azusa, Burbank, Los Angeles North Main, Lynwood, and Rubidoux. In addition, five other neighborhoods were selected because they were thought to be potentially influenced by recreational traffic or heavy-duty truck traffic. These included Long Beach, which appeared to be influenced by truck traffic to and from the Port of Long Beach; Irvine, which is near a route to recreational areas on the Pacific coast; Orange, which is near Disneyland; Ontario, which is near a shopping center; and Highland, which is near a route to recreational areas in the mountains outside the SoCAB. Each of the 10 neighborhoods received an array of loop sensors for vehicle-type counts and at least two sensors for total vehicle counts. The instruments were visited at least once daily for maintenance—this was particularly important for streets with heavy traffic—because the sensor hoses occasionally need to be replaced, as does the tape that holds them onto the street surface.

Figure 2-18. Traffic counter locations in the South Coast Air Basin.

At the end of the deployment period, raw data were downloaded from each instrument, processed into 15-minute intervals, and analyzed. Total daily traffic volumes were calculated for each site by date. Then, data from vehicle classification counters were processed so that traffic volumes by major vehicle class (passenger vehicles, medium-duty trucks, heavy-duty trucks, and buses) could be calculated for each date of deployment. Finally, a 15-minute moving average was constructed for each counter and then normalized to the daily total volume so that diurnal variations in the data could be examined. On the basis of initial quality assurance procedures, data from three classification counters were deemed extremely suspect and not included in the final results. Data from one of the total vehicle counters in the Lynwood neighborhood—Location 39 on Long Beach Boulevard north of Imperial Highway—were also excluded due to an instrument malfunction that occurred after two days of operation. Nearly all the data collected with the remaining 31 traffic counters passed quality assurance review and are presented in Appendix D.

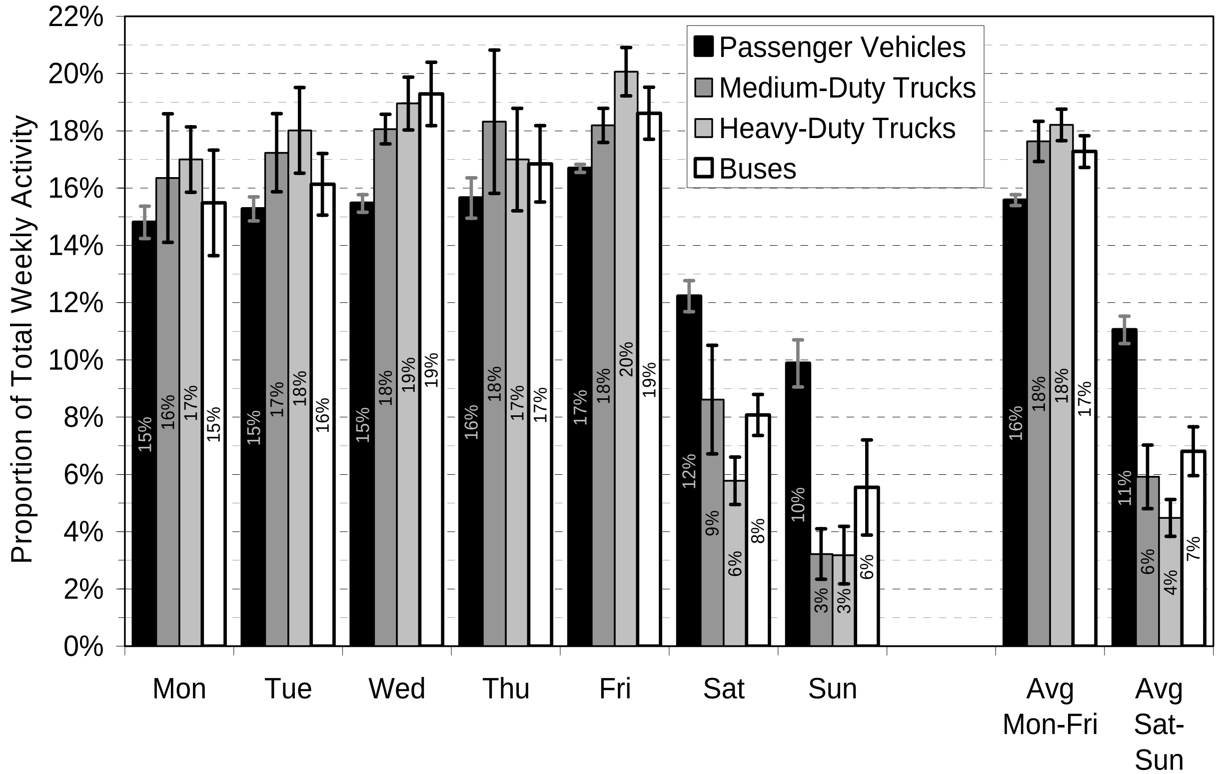
For surface streets, average daily normalized traffic volumes were calculated by road class (see **Figure 2-19**). The average weekday volume fraction was consistently higher than the average weekend volume. On weekends, local streets captured the lowest percentage of weekly volume (10%), followed by collectors (11%), and arterials (12%).[4] An average weekday volume fraction of 15% was detected on all three road classes. This represents a 20-33% drop in total daily travel activity on weekend days relative to weekdays. Travel activity patterns were also found to vary by vehicle type. **Figure 2-20** shows that total daily travel activity for buses and trucks dropped 59-78% on weekends, while total daily travel activity for passenger vehicles dropped only 30%. Finally, not only did traffic volumes vary from weekdays to weekend days, but the diurnal distributions of traffic exhibited differences as well. Past studies have shown a bimodal distribution in the diurnal pattern of traffic activity on weekdays and single-mode patterns on weekends. These patterns were again observed in the surface street results, as illustrated by the example shown in **Figure 2-21**. Time series plots for all surface street traffic counters are shown in Appendix D.



(Error bars are ± 1 standard error of the mean.)

Figure 2-19. Average day-of-week traffic patterns observed for surface streets by road class.

[4] A local street provides access within residential neighborhoods, commercial, and industrial districts; a collector is an urban street that channels traffic from local streets to minor and major arterials and secondarily provides access to residential neighborhoods, commercial, and industrial districts; and an arterial is a roadway that serves major traffic movements and secondarily provides access to abutting land (Harvey and Deakin, 1993).



(Error bars are ± 1 standard error of the mean.)

Figure 2-20. Average day-of-week traffic patterns observed for surface streets by vehicle class.

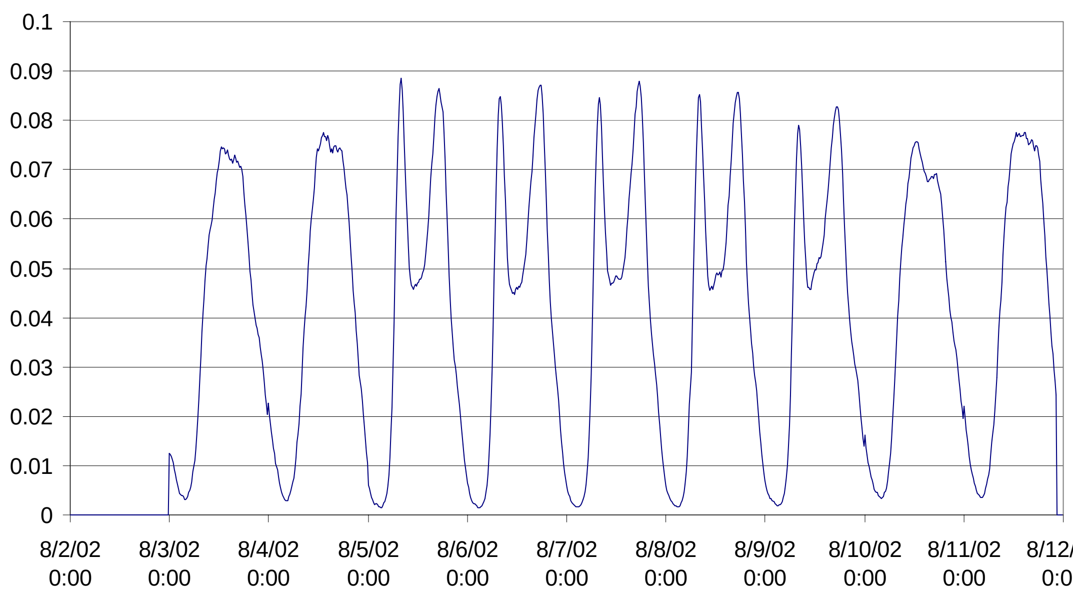


Figure 2-21. Time series of normalized traffic volume for the Irwindale Avenue traffic counter in Azusa, California. (Volume is normalized to total daily volume.)

2.3.2 Caltrans' Freeway Weigh-in-Motion Sites

Traffic volume data for freeways were acquired for Caltrans WIM sites throughout the SoCAB. The WIM network consists of sensors embedded in freeways that instantaneously record the number, weight, and speed of passing vehicles. The data are binned by 14 vehicle classes based on vehicle weight and axle spacing. The standard Caltrans protocol for processing WIM data is to summarize, quality assure, and archive two weeks of data per month for every site. For this study, data were acquired for 12 WIM sites, labeled with site names in **Figure 2-22**. Ten of these sites (all those labeled in Figure 2-18 except Fontana and Peralta) yielded sufficient data to support further analyses and data summaries.

Figure 2-22. Locations of the WIM sites used in this study.

Traffic volumes and fleet mixes were analyzed for each WIM site. Vehicle classifications were assigned to two major categories: light-duty vehicles and heavy-duty vehicles. Passenger vehicles and other vehicles with two or three axles were categorized as light duty, while vehicles with four or more axles were designated heavy duty. Traffic volumes were then analyzed by day of week, hour of day, and vehicle type.

Appendix E provides time series plots for each of the 12 WIM sites evaluated during this study. Generally, the WIM sites experienced bimodal traffic volume patterns on weekdays—similar to those observed on surface streets—with peaks corresponding to the morning and afternoon rush hours (at about 7:00 a.m. and 5:00 p.m., respectively). On weekends, single-mode distributions were observed with broad peaks centered around 2:00 p.m. These patterns are apparent in **Figure 2-23**, which shows an average diurnal time series plot of light-duty vehicle traffic volumes for 10 sites in the study area that yielded sufficient data to support analyses and data summaries. At these sites, total traffic volumes were about 10% lower on Saturday and about 25% lower on Sunday than the average weekday volume.

Weekend volumes of light-duty vehicles were relatively high at the Castaic and Colton sites, which represented minor deviations from the norm. This phenomenon was more extreme at the Castaic site (see **Figure 2-24**). Proximity of the Castaic site to an amusement park might explain the high number of passenger vehicles passing the WIM site to and from the Los Angeles area on weekends. Another reasonable explanation is that the Castaic site, which is positioned in a major corridor to the north of the SoCAB, may be affected by weekend vacation traffic that passes through the area. Colton is located on Interstate 10, a major interstate that carries traffic in and out of the SoCAB. Interstate 10 also leads to popular weekend destinations such as Palm Springs and Death Valley. Observed light-duty-vehicle traffic is higher on Fridays, Saturdays, and Sundays at the Colton site relative to the WIM sites within the SoCAB. Increased light-duty-traffic volumes on weekends may be explained by people traveling out of the basin to recreation destinations on Friday and Saturday and returning to the SoCAB on Sundays

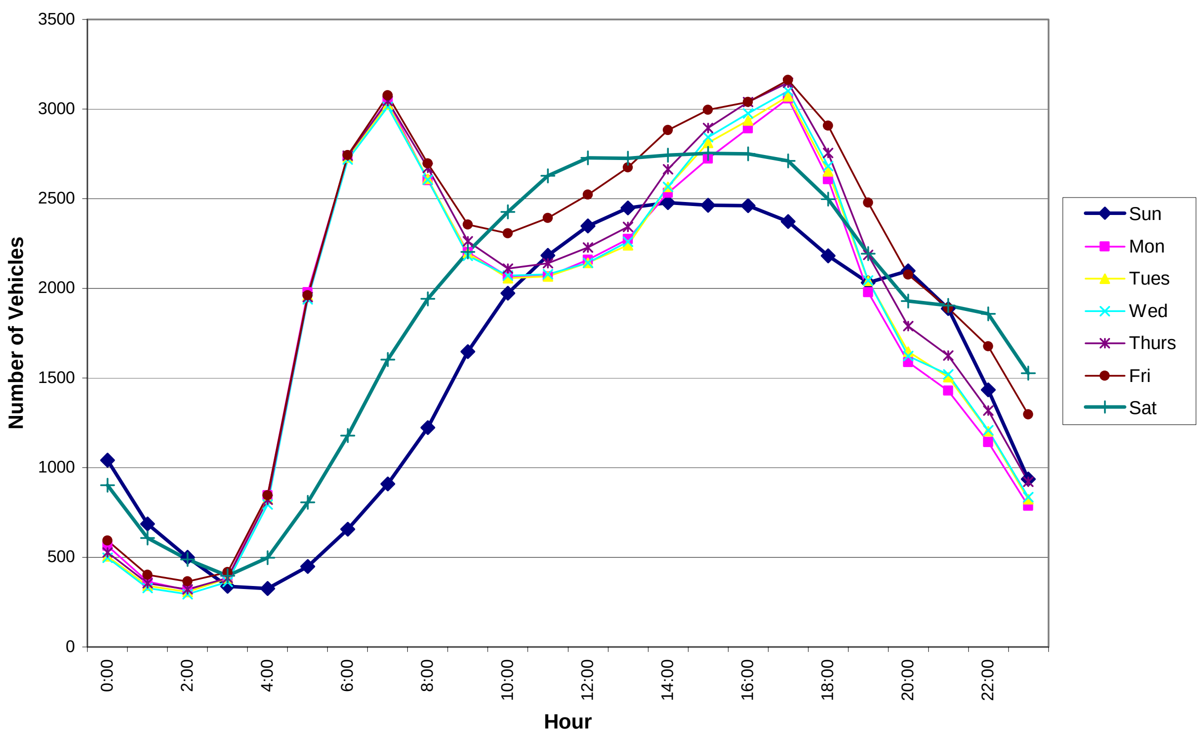


Figure 2-23. Diurnal time series plot for light-duty vehicles.

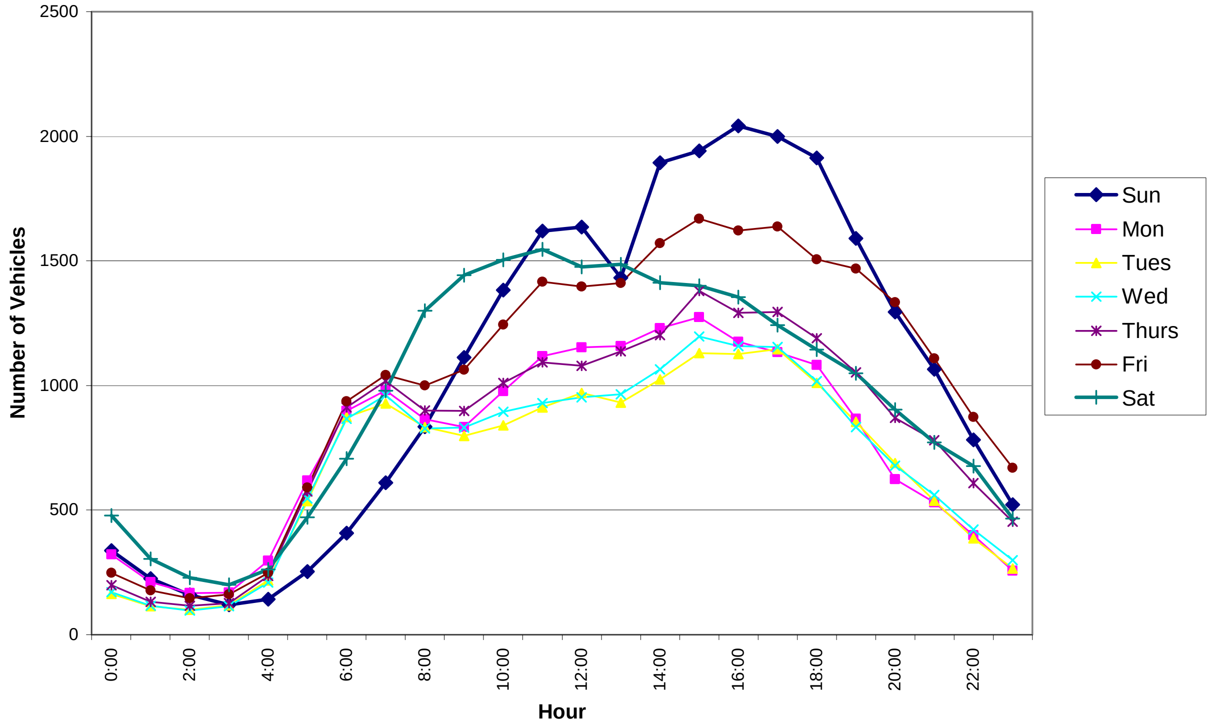


Figure 2-24. Diurnal time series plot for light-duty vehicles at the Castaic site.

Heavy-duty daily traffic activity patterns differed from light-duty vehicle traffic patterns as shown in **Figure 2-25**. At 9 of 10 urban sites, total daily heavy-duty traffic volumes declined 50-75% on weekends relative to weekdays. In addition, heavy-duty traffic patterns followed single-mode peaks that occurred at around midday on both weekdays and weekends. The Castaic site was the only exception. At Castaic, heavy-duty traffic followed a weekday bimodal pattern, as shown in **Figure 2-26**.

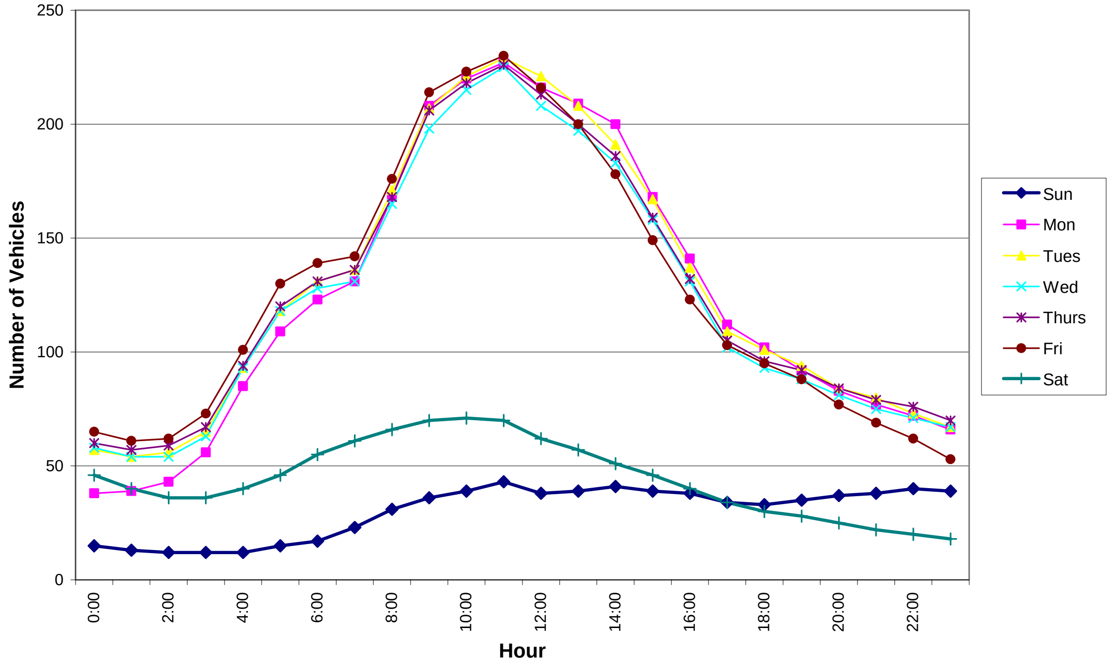


Figure 2-25. Diurnal time series plot for heavy-duty vehicles.

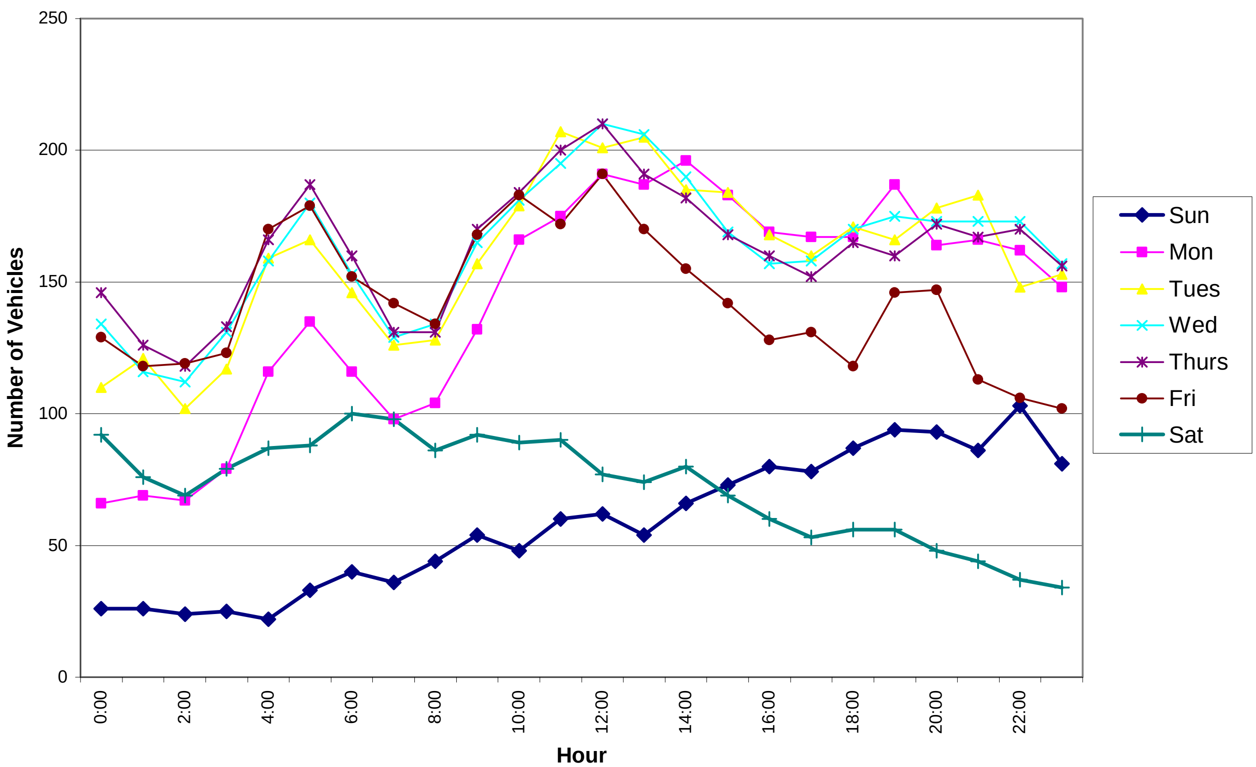


Figure 2-26. Diurnal time series plot for heavy-duty vehicles at the Castaic WIM site.

2.4 SUMMARY OF FINDINGS FOR ON-ROAD MOBILE SOURCES

In brief, we made the following observations based on our analyses of activity data sets for on-road mobile sources.

Based on the telephone and mail surveys of over 800 households

- On average, survey participants own 2.0 vehicles per household.
- Fewer trips occur on Sundays than on any other day of the week.
- On weekends, trips are less likely to occur in the morning than they are on weekdays.

Based on in-vehicle observations for 68 households and 107 vehicles

- Total daily VMT is 0-4% higher on Fridays, 0-24% lower on Saturdays, and 22-33% lower on Sundays than on an average weekday.
- Passenger vehicles may be preferred during the early part of the week (Sunday through Wednesday), while light-duty utility vehicles may be preferred during the later part of the week (Thursday through Saturday).
- While the largest proportions of VMT occur on major highways throughout the week, major highways account for an even higher fraction of total VMT on weekends than on weekdays.
- Travel activity peaks at 0700-0800 and 1600-1700 PST p.m. on weekdays. Travel activity follows a very broad and gradual peak from noon to 1700 PST on weekends.
- A large proportion (between 30% and 40%) of highway VMT occurs at speeds greater than 65 miles per hour. Because current mobile source emission models do not characterize emissions at these speeds, this driving pattern may reduce the accuracy of current emission inventories.
- The number of trips varies from 3.6 to 5.6 trips per day. The frequency of trips remains about 4.8-5.1 per day Monday through Friday, increases to 5.6 per day on Friday, drops to 4.1 per day on Saturday, and drops further to 3.6 on Sunday.

Based on observations from surface streets

- Traffic activities decline 20-27% on Saturdays and 27-33% on Sundays relative to weekdays; however, heavy-duty traffic activities decline to a much greater extent. Heavy-duty traffic activities decline 67-83%.
- Traffic activities follow bimodal distributions on weekdays and single-mode distributions on weekends.

Based on observations at freeway locations

- On average, traffic activities follow bimodal distributions on weekdays and single-mode distributions on weekends. However, heavy-duty activity patterns follow single-mode distributions on all days of the week.

- On average, Saturday volumes generally are 11% lower and Sunday volumes are 26% lower than average weekday volumes. However, heavy-duty volumes declined 50-75% on weekends.
- Exceptions to the norm occur outside the urban core and at locations near recreational attractions.

3. OFF-ROAD MOBILE SOURCES AND AREA SOURCES

During summer 2002, we surveyed residences and small businesses in the SoCAB about the frequencies and timing of various emission-related activities. The objectives of the surveys were to corroborate and extend our findings from surveys conducted in 2000 and 2001 (Coe et al., 2002; Chinkin et al., 2003; Chinkin et al., 2002) and to characterize WD-WE activity patterns for additional seasons and types of area sources. The surveys were concurrent and coordinated with other data collection efforts described in the other sections of this report. Partly to evaluate seasonal effects—our previous work was conducted in the fall—some of the surveys targeted five specific neighborhoods of Los Angeles in the immediate vicinities of key air quality monitoring sites, while the remainder of the surveys was administered to randomly selected samples of residents and businesses throughout the SoCAB. Our previous analyses were limited by several factors:

- They were carried out for specific neighborhoods of Los Angeles, which may not have been representative of the entire Los Angeles Air Basin.
- They were conducted in September and October of 2000 or 2001, which may not have been representative of summertime conditions.
- Sample sizes were small for businesses in some cases.
- No WD-WE activity patterns were available for several important source categories: recreational off-road equipment, recreational boats, and heavy-duty construction equipment.

The results presented in this section remedy each of these limitations and strengthen the preliminary conclusions we reached during our earlier work. We surveyed (1) respondents who were selected randomly throughout the SoCAB and (2) respondents who were located in two of the neighborhoods surveyed in 2000-2001 and in three additional neighborhoods. In addition, our latest study occurred during the summer. By cross-comparing the various results, we have confirmed that our earlier results were reasonably representative of summertime activity patterns throughout the SoCAB.

3.1 METHODS

Data were collected by telephone and mail surveys of households and commercial entities in five specific neighborhoods in the SoCAB within 4 km of an ambient air quality monitoring site (see **Figure 3-1**) and throughout the SoCAB, which includes Orange County and portions of Los Angeles, Riverside, and San Bernardino Counties. (Survey instruments—telephone and mail questionnaires—are reproduced in Appendix C.) The study period—May 17, 2002, through September 16, 2002—coincided and coordinated with other WD-WE data collection efforts in the Los Angeles area (described in other sections of this report). We did not collect data during the weeks of Memorial Day, Independence Day, and Labor Day.

Households were recruited in advance by telephone and by mail. After initial telephone recruitment, each residential survey participant received a letter; a daily activity diary in the form of a booklet of 10 postcards (which were date-stamped and postage-paid); and an attractively packaged one-dollar coin in mint condition (to encourage continued participation). Each participant was asked to complete one postcard per day for return by mail, beginning on a Friday and finishing 10 days later on a Sunday. Thus, each household completed postcards for two Fridays, two Saturdays, two Sundays, and the intervening Monday through Thursday. Participants checked off responses to queries about daily and periodic household activities, including uses of barbecues, recreational boats, recreational off-road vehicles, paints or solvents, personal care products, showers or baths (as a surrogate of water heating), and automatic appliances (also as a surrogate of water heating). Response options included “yes or no” (to ascertain any use that day); as well as “check all that apply: morning, afternoon, evening” (to determine the time periods when use occurred).

In addition, household participants responded at the time of initial recruitment to a telephone survey that established the following household characteristics: (1) number of persons in the household; (2) number of household members who regularly attend work or school outside the home; (3) number of males, females, legal adults, and legal minors who are members of the household; (4) total number of passenger cars, RVs, trucks, SUVs, vans, and/or motorcycles owned by household members; (5) ownership of any off-road recreational vehicles and corresponding counties where typically used; (6) ownership of any recreational boats or other watercraft and corresponding counties where typically used; (7) presence of a barbeque grill in the home and corresponding fuel types; (8) type of home heating and type of water heating and corresponding fuel types; (9) type of residence (e.g., single-family, multi-family); (10) status of home ownership versus rental; and (11) range of household income.

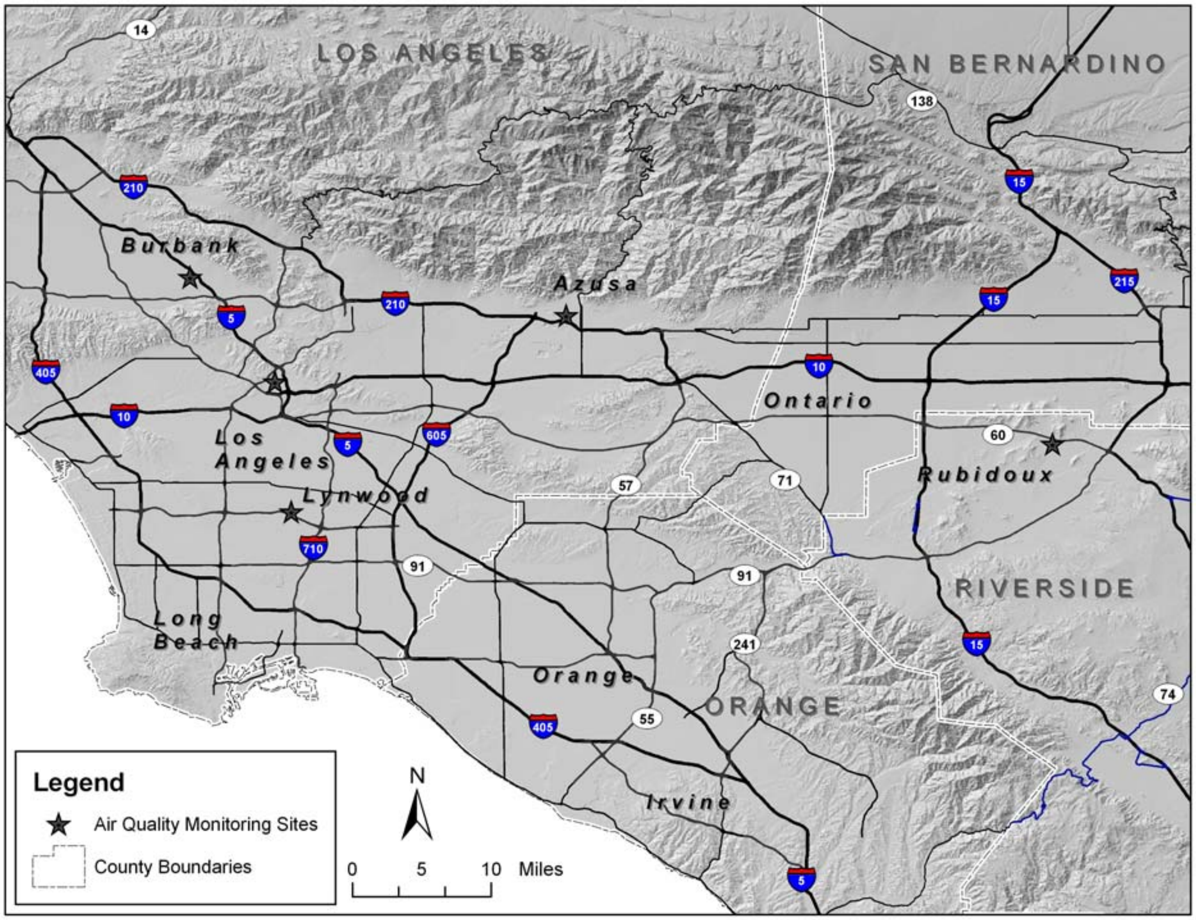


Figure 3-1. Locations of five neighborhoods near air quality monitoring stations—Burbank, Azusa, downtown Los Angeles, Lynwood, and Rubidoux—targeted for extra attention with the surveys.

Commercial entities were contacted for participation in a short telephone survey and were asked a series of detailed questions about the number of employees typically on duty during specific time periods. The numbers of employees on duty were established for each day of a seven-day week and for six four-hour work shifts starting at midnight. Numbers of employees on duty were taken as indicators of business activity levels. The telephone recruitment and interview of commercial entities included a series of questions to determine the following business characteristics: (1) type of workplace (office or other); (2) total number of employees; (3) business hours of operation by day of week; (4) use of gas ovens or commercial charbroilers; (5) use of paints or solvents; (6) use of light-duty off-road industrial equipment with internal combustion (IC) engines; or (7) use of heavy-duty off-road equipment with IC engines; (8) use of motor oils (including gear oils, gear fluids, or brake fluids); or (9) use of pesticides or fertilizers.

An additional survey of construction businesses was conducted to characterize activity levels for heavy-duty construction equipment. Like the general commercial survey described above, respondents were asked about the number of heavy equipment operators typically on duty for each day of a seven-day week and for six four-hour work shifts. In addition, participants responded to questions about several business characteristics: (1) predominant construction contract type (e.g., residential development, commercial facilities, industrial complexes, roads, etc.); (2) number of offices and locations; (3) number of in-progress projects per year; and (4) types of construction activities typically performed (e.g., site preparation, foundation development, framing, etc.).

3.2 RESULTS

3.2.1 Summary of Survey Participation

Table 3-1 tabulates the outcomes of all contacts with potentially qualified respondents. Because both sets of residential survey results—the randomly selected group and the group chosen from specific neighborhoods—were very similar to one another, they were combined in our analyses. Refusal rates of 25% or less for the business surveys and 40% to 45% for the residential telephone surveys were observed. (In our experience and in the experience of the market research firm that conducted the surveys, these refusal rates are typical for business and residential surveys.) Of 870 households that were recruited for the mail survey, 488 successfully completed and returned at least one postcard; 380 (44%) completed and returned all 10 postcards; and 423 (49%) completed and returned at least eight postcards. Of the 8700 postcards that were mailed to residential survey participants, 4410 (51%) were returned. Similar numbers of postcards were received for each day of the week, Sunday through Saturday (from 418 to 472 postcards per day). On average, participants' postcard return rates declined slightly—by about 11%—over the course of their 10-day participation in the mail surveys. Respondents indicated that 3220 (73%) of returned postcards had been completed on the day of interest and that 674 (15%) of returned postcards were completed within one day after the day of interest.

Table 3-1. Dispositions of contacts made to potentially qualified survey respondents.

Disposition Status	Residential Survey: Specific Targeted Neighborhoods		Residential Survey: Randomly Selected Participants		Residential Survey: All Participants		Commercial Survey		Heavy-Duty Construction Equipment Survey	
	No. of Respondents	% of Total	No. of Respondents	% of Total	No. of Respondents	% of Total	No. of Respondents	% of Total	No. of Respondents	% of Total
Potentially qualified	2704	100	2776	100	5480	100	559	100	1659	100
Unavailable*	1066	39	1295	47	2361	43	342	61	989	60
Refused participation	1167	43	1082	39	2249	41	80	14	412	25
Participated in telephone survey	471	17	399	14	870	16	137	25	258	16
Participated in postcard survey	260	10	228	8	488	9	NA	NA	NA	NA

* Could not be reached after six to eight call attempts.

In terms of household characteristics, both sets of residential surveys were again very similar to one another and were combined in our analyses. On average, participating households had 3.2 household members and owned 2.0 on-road vehicles. 50.6% of households reported an annual income of $50,000 or less. The home ownership rate was 58.3%, with 7.9% of participating households owning an off-road recreational vehicle, 5.5% owning a boat, and 68.9% owning a barbecue grill. Gas was the predominant means of heating both homes (74.8%) and water (80.9%). These statistics corroborated those obtained in our previous study, though ownership rates of off-road recreational vehicles (3.8%) and barbecue grills (57.3%) were somewhat lower in the earlier survey.

The general commercial survey respondents employed 3254 workers and the construction business survey respondents employed approximately 10,000 construction workers, including 2158 heavy equipment operators. In aggregate, the participating construction businesses emploedy approximately 15% of all construction workers in the SoCAB counties (relative to total employments reported by the U.S. Census Bureau for General Building Contracting and Heavy-duty Construction [U.S. Census Bureau, 2003]). **Table 3-2** illustrates the types of construction businesses that participated in the construction survey.

Table 3-2. Distribution of participating construction businesses by type.

Type of Construction*	Number of Respondents
Residential	135
Commercial	163
Industrial	87
Road	87
Waterway	25
Total Respondents	293

* Some businesses performed more than one type of construction.

3.2.2 Residential Survey Results

Figure 3-2 illustrates the positive response rates (PRR) that were observed for questions about seven residential activities, calculated for each day of week as follows:

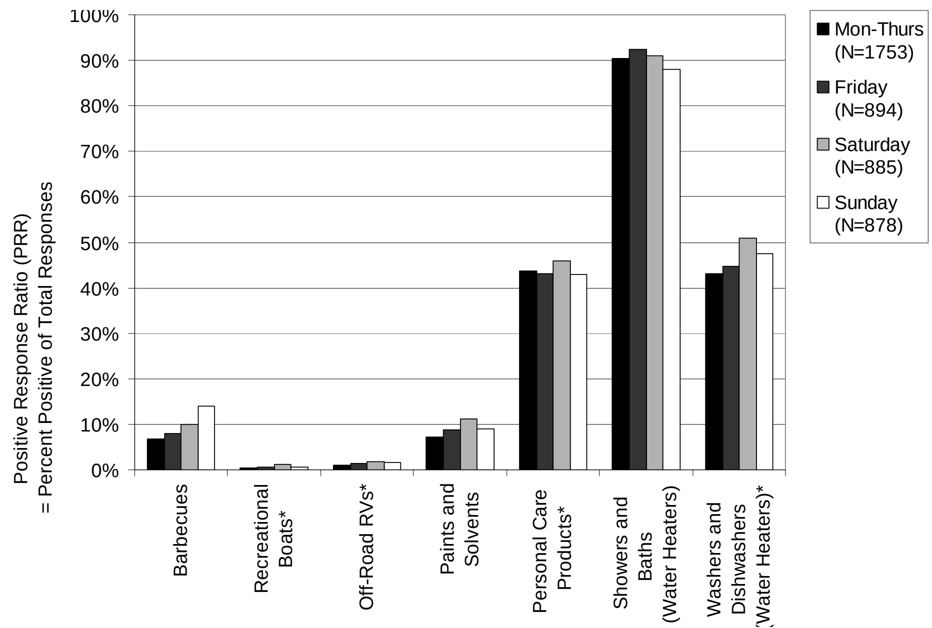
$$PRR_i = N_{positive,i} \div N_{total,i} \times 100\% \qquad \textbf{(3-1)}$$

where:

$N_{positive}$ = number of postcards that positively indicated that an activity occurred on the day of interest

N_{total} = total number of postcards received for the day of interest

i = the day of week of interest



(N=Total number of postcards received.)
*Indicates corroborating results for findings from 2000-2001 (Coe et al., 2002).

Figure 3-2. Positive survey response rates by day of week for residential activities.

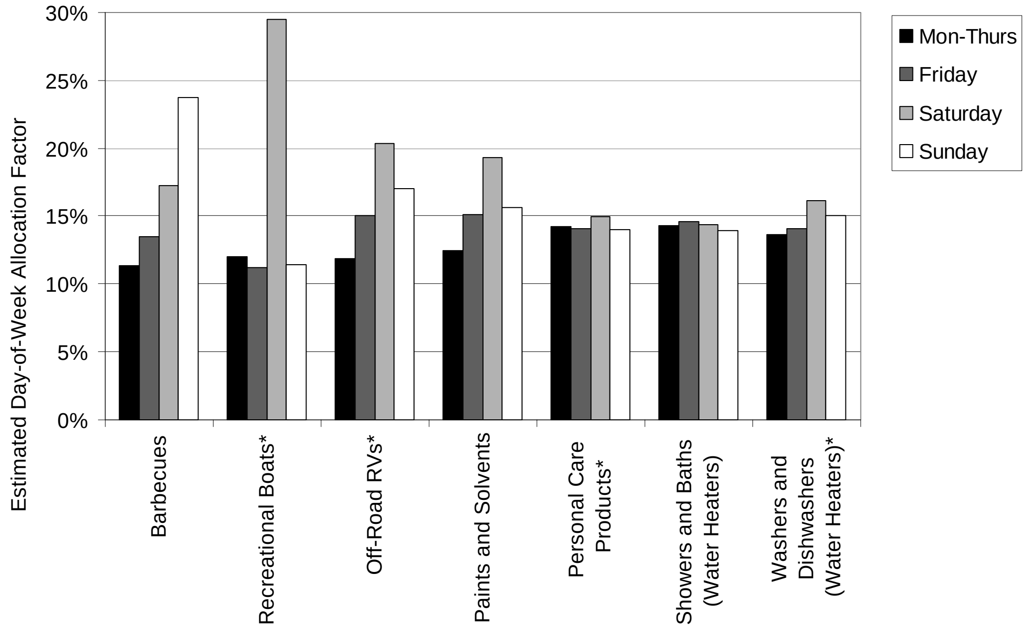
Figure 3-3 illustrates day-of-week allocation factors (AF_{DOW}) that were estimated directly from the residential survey data. These were calculated as follows:

$$AF_{DOW,i} = PRR_i \div (4 \times PRR_{M\text{-}Th} + PRR_{Fri} + PRR_{Sat} + PRR_{Sun}) \times 100\% \qquad \textbf{(3-2)}$$

where:

$AF_{DOW,i}$	=	day-of-week allocation factor for day *i*
$PRR_{M\text{-}Th}$	=	positive response rate for the group of days, Monday through Thursday
PRR_{Fri}	=	positive response rate for Friday
PRR_{Sat}	=	positive response rate for Saturday
PRR_{Sun}	=	positive response rate for Sunday

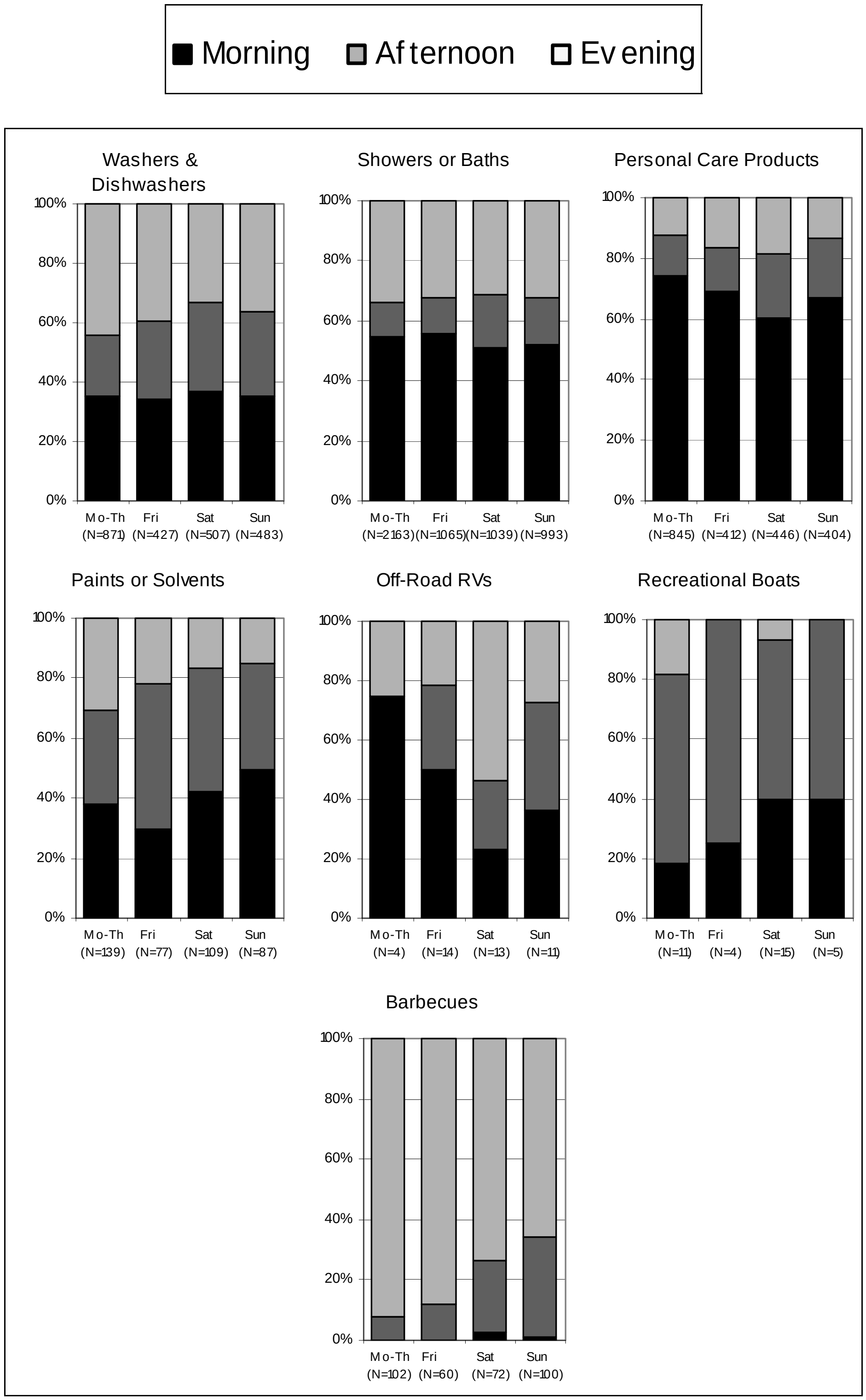
Figures 3-2 and 3-3 show that occurrence of several residential activities increased (25% to 165%) on Saturdays or Sundays (relative to weekdays). These activities included the uses of barbecues, recreational boats, recreational off-road vehicles, and paints or solvents. Other activities varied little by day of week, including the use of personal care products and water heaters for showers, baths, or automatic home appliances. For the categories marked by asterisks in Figures 3-2 and 3-3, the results generally corroborated data that were gathered in 2001-2001 (Coe et al., 2002; Chinkin et al., 2003; Chinkin et al., 2002). Only two modest exceptions occurred. In contrast to the 2000-2001 studies, the Saturday usage rate of barbecues in 2002 decreased by about 30%. In addition, a slight increase in weekend use of paints and solvents (relative to weekdays), which was observed in 2000-2001 but considered to be statistically insignificant (due to the small number of respondents indicating the use of paints and solvents), now appears to be statistically significant with the addition of the 2002 data sets. Otherwise, the fall 2000-2001 and summer 2002 data sets were practically indistinguishable.



*Indicates corroborating results for findings from 2000-2001 (Coe et al., 2002).

Figure 3-3. Survey-based estimated day-of-week allocation factors for residential activities.

Figure 3-4 illustrates the distribution of positive responses by time of day for various residential activities. Use of barbecues tended to occur in the evenings, while use of personal care products tended to occur in the mornings. Residential use of paints or solvents tended to occur during mornings and afternoons, but rarely in the evenings. Diurnal patterns of some activities varied somewhat by day of week. On weekdays, about 90% of barbecue use occurred during the evenings. However, afternoon use of barbecues increased from 8% of total daily use, Monday through Thursday, to about 30% on weekends. In contrast, diurnal variations for residential uses of water heating for showers, baths, automatic dishwashers, and clothes washers were fairly constant and seemingly not WD-WE dependent. Survey respondents infrequently indicated the use of recreational boats and off-road recreational vehicles. Therefore, insufficient time-of-day observations are available for these activities to draw conclusions about day-to-day variabilities in their diurnal patterns.



N = Total number of time-of-day responses received. Note that not all positive responses (Figure 3-2) were associated with time-of-day responses, presented above.

Figure 3-4. Distributions of positive survey response rates by time of day for residential activities.

3.2.3 Commercial Survey Results

The results from the 2002 general commercial survey concurred with 2000-2001 survey results (Coe et al., 2002). Corroborated information included (1) WD-WE distributions of work performed throughout the typical work week and (2) distributions of work performed throughout the typical work day. Results demonstrated that commercial activities decline from 60% to 99% on weekends. Because the 2002 general commercial survey and its results were so similar to the 2000-2001 surveys, data sets were combined to yield a greater degree of statistical confidence and to facilitate analyses of the subgroups for which numbers of respondents were very small, such as businesses that operate gas ovens or perform other specific operations. The results of the combined surveys show that, in general, business activities peak in the 8:00 a.m.-to-4:00 p.m. time frame on weekdays, while weekend activities are more evenly distributed throughout the day. Sundays show the most even distribution of business activity throughout the day. Exceptions include companies that operate garden equipment or heavy-duty construction equipment, which peak early, and businesses that use gas ovens, which peak late on weekdays and sustain high levels of activity through the evening.

Figure 3-5 illustrates business activity levels, or estimated person-hours worked, by day of week and time of day for various types of businesses, including all surveyed businesses, workplaces that reported specific types of equipment in use, and businesses that responded to the survey of construction activities. The number of person-hours worked (W) was estimated as follows:

$$W = E \times t \qquad \textbf{(3-3)}$$

where:

E	=	number of employees on duty for the time period of interest
t	=	length of the time period of interest (hours)

For all types of businesses in aggregate, weekend activity levels declined from weekday levels by 74% and 82% on Saturdays and Sundays, respectively (see **Table 3-3**). However, declines in activity levels on weekends varied somewhat by type of business. At one extreme, construction companies experience reductions in activity levels from 90% to 99% on Saturdays and Sundays. At the other extreme, businesses that operate gas ovens had activity levels that were only 61% lower on Saturdays. **Figure 3-6** illustrates day-of-week allocation factors (AF) that were developed for commercial activities and calculated as follows:

$$AF_i = W_i \div (5 \times W_{M\text{-}F} + W_{Sat} + W_{Sun}) \times 100\% \qquad \textbf{(3-4)}$$

where

AF_i	=	day-of-week allocation factor for day *i*
$W_{M\text{-}F}$	=	average number of person-hours worked for Monday through Friday
W_{Sat}	=	average number of person-hours worked for Saturday
W_{Sun}	=	average number of person-hours worked for Sunday

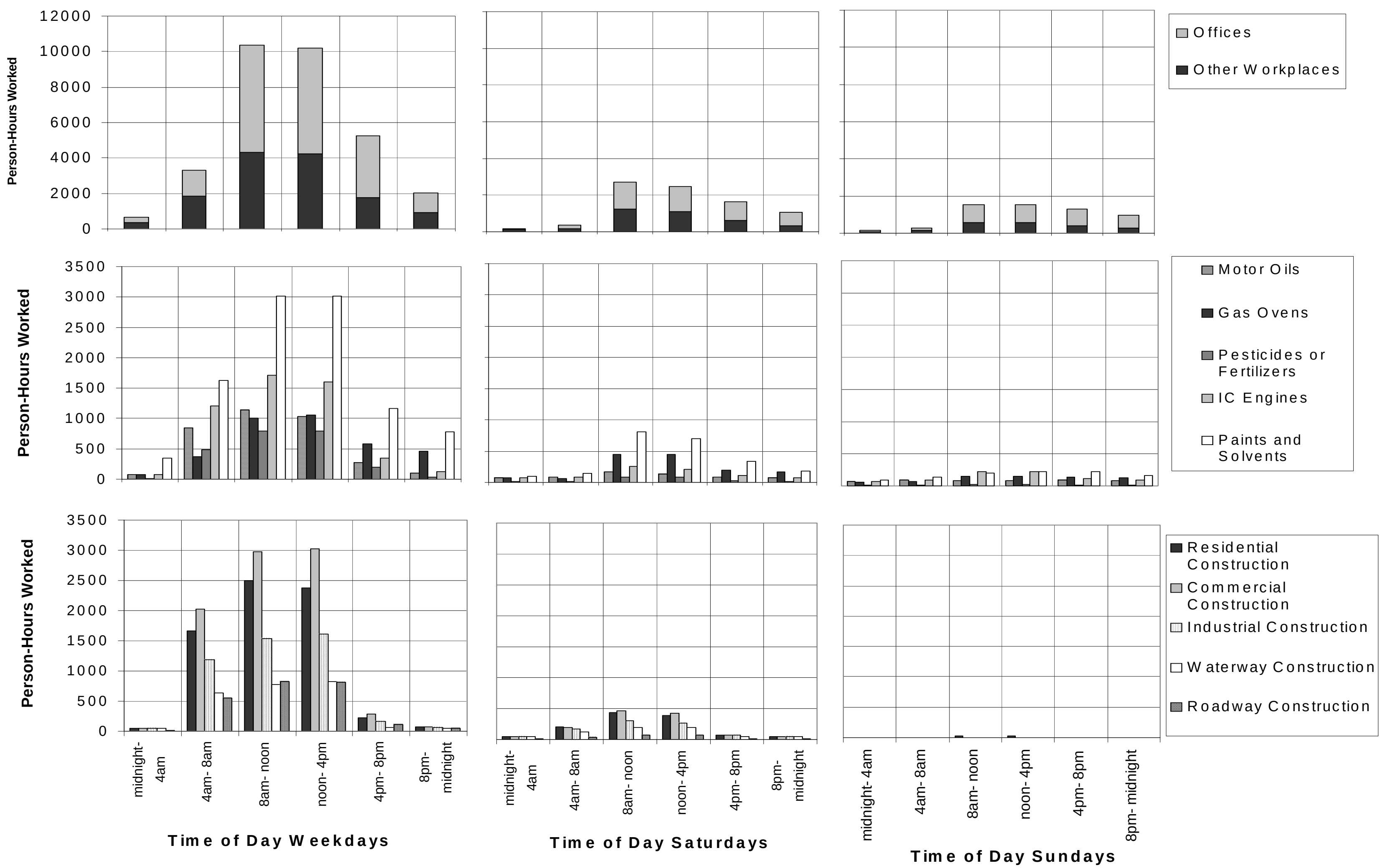


Figure 3-5. Business activity levels (person-hours worked) by day of week and time of day for all businesses by type of workplace (top row), workplaces with equipment in use (middle row), and construction companies (bottom row).

Table 3-3. Weekend reductions in activity for various types of surveyed businesses.

Type of Business	N	NE	Percent Reduction in Activity Level Relative to Weekdays	
			% Saturday Reduction	% Sunday Reduction
All businesses	267	3254	74	82
Offices	162	1823	74	80
Other workplaces	105	1431	73	84
Businesses with equipment in use	68	1187		
Gas Ovens	14	373	61	80
IC Engines	25	454	84	84
Motor Oils	16	297	82	86
Paints or Solvents	44	991	77	89
Pesticides or Fertilizers	20	225	91	96
Lawn and Garden Equipment*	156	5475	91	94
Construction Equipment*	293	2158	90	99

N = Number of businesses sampled; NE = Number of workers employed by sampled businesses.
* Surveys of commercial-use lawn and garden businesses and businesses with heavy construction equipment data were collected separately from surveys of other types of businesses.

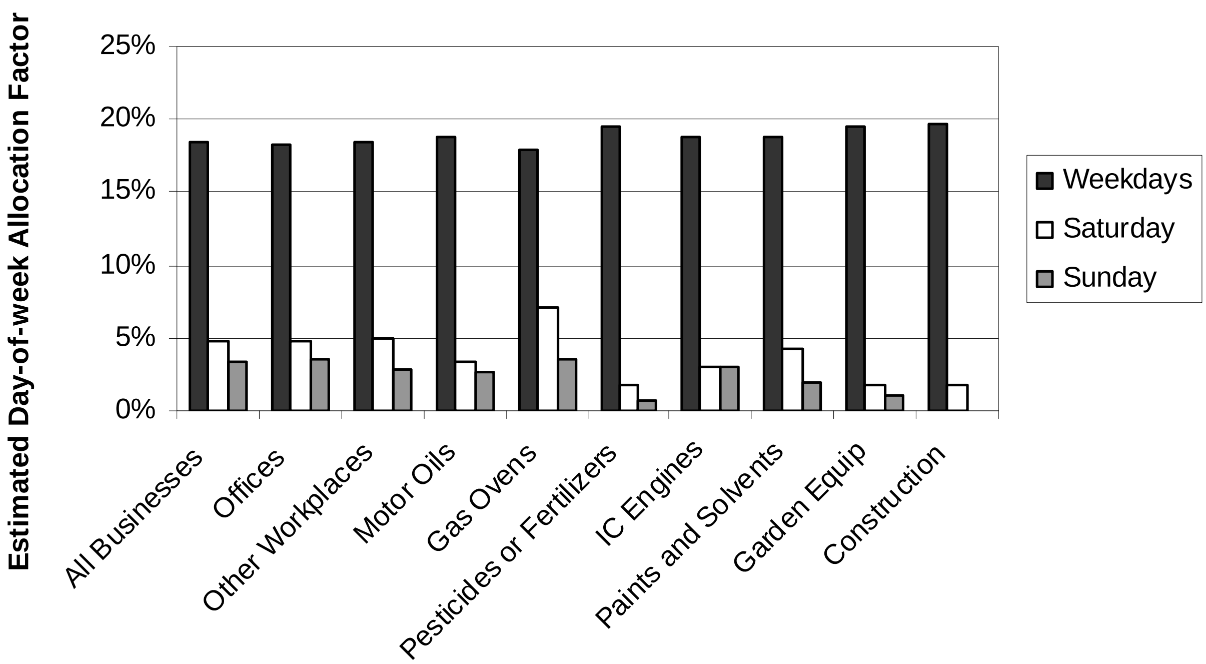


Figure 3-6. Estimated day-of-week allocation factors for business activities.

Figures 3-7 and 3-8 show distributions of person-hours worked by time of day for the general business surveys and for the construction business surveys, with information provided for specific types of equipment and construction activities. On weekdays, daily business activity levels peak from 8:00 a.m. to 4:00 p.m. However, individual types of businesses differ from the aggregate pattern. Businesses that use gas ovens peak in activity levels later in the day, from noon to 4:00 p.m., and have relatively large proportions (between 15% and 30%) of daily activity during evening hours. Activity levels for both lawn and garden care services and construction companies peak much earlier in the day with over 90% of their activities occurring between 4:00 a.m. and 4:00 p.m. With the exception of companies that perform lawn and garden services, Saturdays and Sundays show a more consistent level of activity throughout the 24-hr day compared to the peak observed for most businesses during a typical weekday. In contrast, Sunday levels for lawn and garden activities are dominated almost entirely by two shifts from 8:00 a.m. until 4:00 p.m.

Figure 3-8 depicts WD-WE and time-of-day activity variations for construction companies in aggregate and for specific types of construction: residential, commercial, industrial, waterway, and road construction. For the construction industry as a whole and for each specific type of construction activity, approximately 90% of weekday activity occurs from 4:00 a.m. through 4:00 p.m. Also, construction companies have a large peak in activities on weekends from 8:00 a.m. to 4:00 p.m., unlike most other types of businesses whose weekend hours are more evenly distributed over 24 hours. In addition, some differences are apparent in weekend patterns for specific types of construction. On Saturdays, approximately 20% of work by waterway and road construction companies occurs between 4:00 p.m. and 4:00 a.m., whereas the industry as a whole conducts a smaller proportion—about 10%—of their work on Saturdays during that period. In addition, only 2 of 135 residential construction companies surveyed reported that any work was performed on Sundays.

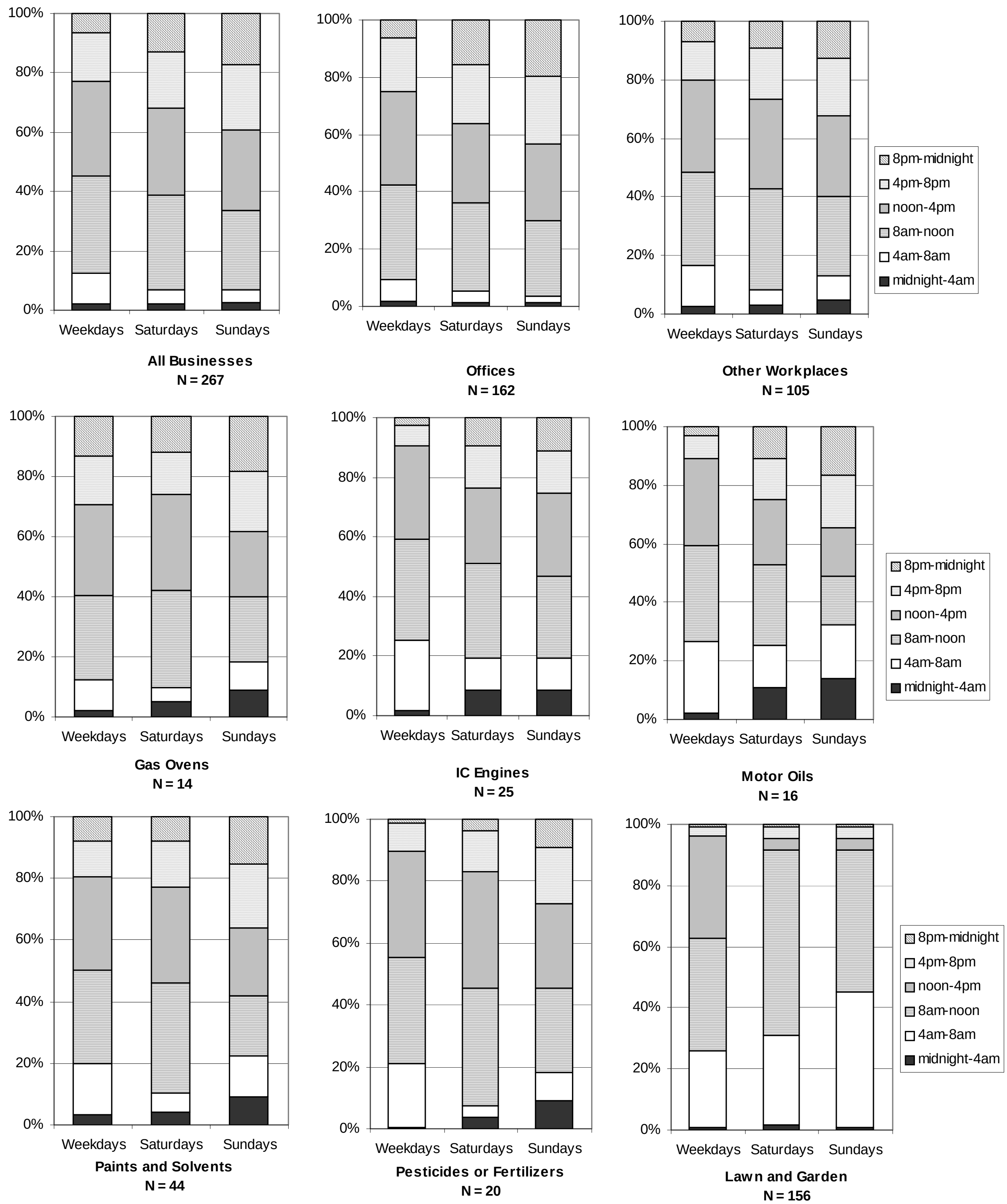


Figure 3-7. Diurnal distributions of person-hours worked for business activities. (N = number of responses received.)

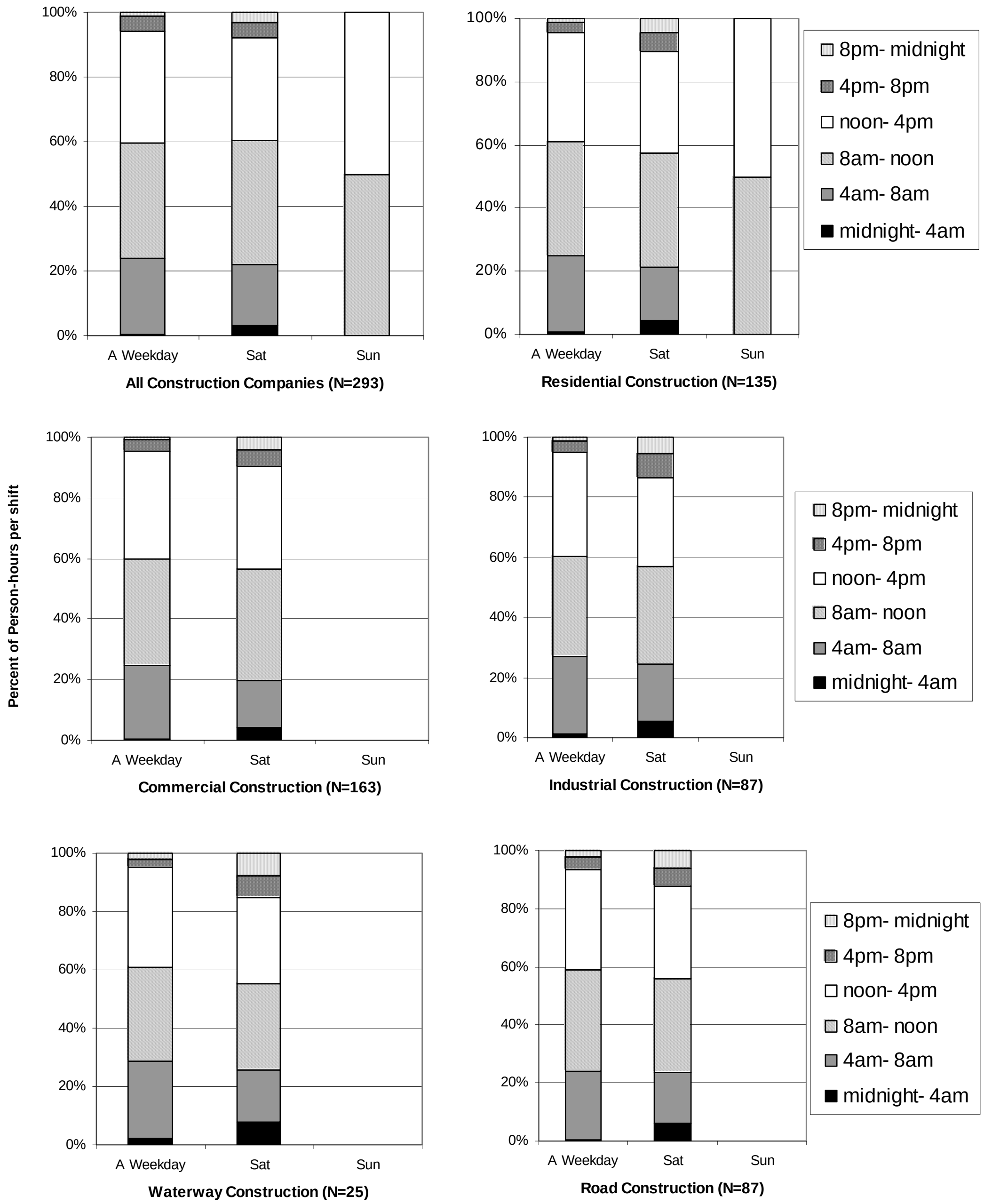


Figure 3-8. Diurnal distributions of person-hours worked for the construction business as a whole and for specific sectors. (N = number of responses received; some businesses performed more than one type of construction.)

3.3 SUMMARY OF FINDINGS FOR OFF-ROAD MOBILE SOURCES AND AREA SOURCES

In summary, survey data presented here suggest that aggregate variations in human behaviors, which follow WD-WE patterns, affect WD-WE emission rates of ozone precursors. The following conclusions were drawn from the survey data:

- Some residential activities increased significantly from weekdays to weekends (25% to 165%, as shown in Figure 3-3), which corroborated previously presented data (Coe et al., 2002). Activities that increased included residential use of barbecues, recreational boats and off-road vehicles, and paints or solvents. However, it is important to note the very small sample sizes observed for recreational boats and off-road vehicles, as shown n Figure 3-2.
- In addition, diurnal patterns for some residential activities varied by day of week. For example, weekday use of barbecues occurs primarily in the evening. However, afternoon use increases from about 10% of daily activity, Monday through Thursday, to about 30% on weekends. Other types of activities varied less than 25% by day of week, including residential uses of personal care products and water heating for showers, baths, and automatic home appliances.
- Diurnal distributions for some residential activities varied by day of week. For example, on weekdays, approximately 88% or more of barbecue use occurred during the evenings. But on weekends, afternoon use of barbecues increased from 10% to about 30% of total daily use. Little or no WD-WE dependence was observed in the diurnal patterns for water heating.
- Business activities declined by 60% to 99% on weekends when measured in terms of person-hours worked. The activity levels of most types of businesses peaked from 8:00 a.m. to 4:00 p.m. on weekdays, leveled somewhat on Saturday, and achieved a relatively flat distribution all periods of the day on Sundays. Exceptions were lawn and garden businesses and construction businesses, which peaked from 4:00 a.m. to 4:00 p.m. on weekdays and conducted almost no work on Sundays. Exceptions also included businesses that use gas ovens, which peaked slightly later in the day on weekdays and sustained high levels of activity through the evening hours and weekends.
- Household characteristics (e.g., number of household members, number of vehicles, household income) and response rates were very similar when the neighborhood and SoCAB-wide survey results were compared. Because all surveys were comparable and produced similar results, we are able to combine data sets, increase the sample sizes, and therefore increase confidence in our earlier findings. In addition, because this study produced new information about WD-WE activity patterns for recreational off-road equipment, recreational boats, and heavy-duty construction equipment, it appears that the WD-WE shifts in ROG:NO_x emission ratios are more pronounced than previously estimated. This occurs because activity levels for recreational vehicles and boats, which emit more ROG than NO_x, increase on weekends compared to weekdays, while activity levels for heavy-duty construction equipment, which emit more NO_x than ROG, decrease on weekends compared to weekdays. Thus, it appears that the ROG:NO_x ratio increases on weekends relative to weekdays to an even greater extent than we previously estimated (Coe et al., 2002; Chinkin et al., 2003; Chinkin et al., 2002).

4. POINT SOURCES

4.1 METHODS

Continuous emission monitoring systems (CEMS) data for May-October 2002 were provided by the SCAQMD for 84 unique facilities in Los Angeles County and the surrounding counties of Orange, Riverside, and San Bernardino. The SCAQMD removed all confidential information, such as facility names, before providing the data. We developed quantitative summaries and statistical analyses of these data to assess WD-WE variabilities in NO_x emissions for major point sources in the SoCAB.

4.2 RESULTS

Of the 84 facilities for which SCAQMD provided CEMS data, 78 reported NO_x emissions during the time period of interest. Of these, the 19 largest NO_x emitters accounted for 82% of total NO_x emissions during the summer months. The CEMS data set was nearly complete for these 19 largest NO_x emitters (with very few missing or zero values). Therefore, although approximately 17% of the complete data set contained missing or zero values, it is unlikely that these potentially problematic data points would significantly affect our conclusions about *total* NO_x emissions (as opposed to facility-specific emissions) for major point sources in the SoCAB under most conditions. However, we normalized or corrected data when necessary to remedy biases that were caused by missing data. Time series plots that were prepared for several of the largest NO_x emitters revealed a few emissions spikes that occurred during the time period of interest (**Figure 4-1**). We gave special consideration to these outlying points in our analyses.

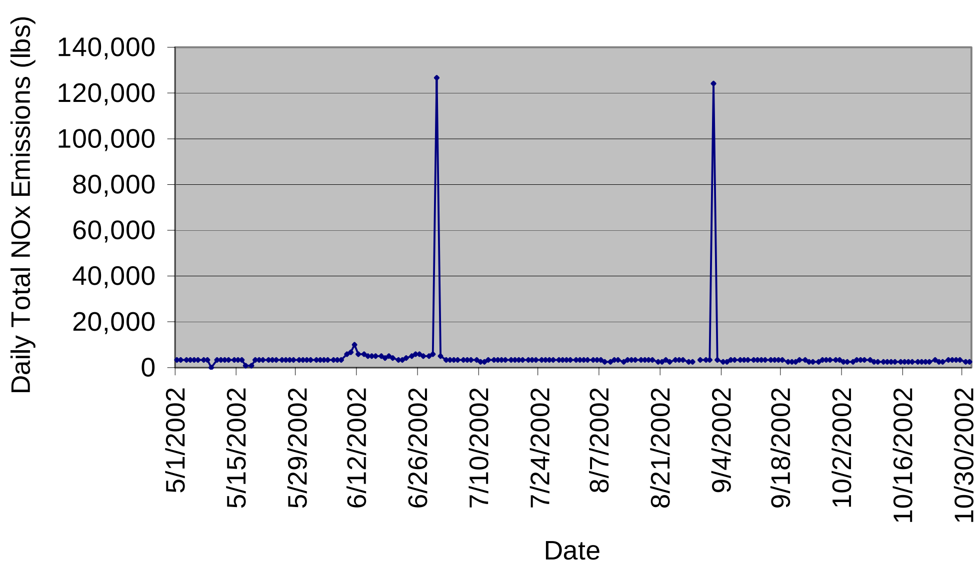


Figure 4-1. Example of a time series plot for a major point source showing emissions spikes in late June and early September 2002.

In order to assess WD-WE emissions patterns, total emissions were averaged by day of week (**Figure 4-2**). To produce representative averages, it was necessary to minimize the effect of an extreme outlying data point observed at one facility on Sunday, June 30. To normalize the effect of the outlier, NO_x emissions for Sundays were recalculated for this facility by replacing the outlying value with the average of the values observed on all other Sundays at the facility during the summer months. The corrected results show that total emissions remained steady from Monday through Thursday, and dropped by about 6% from Friday through Sunday. (Figure 4-2 also shows the results without the correction.)

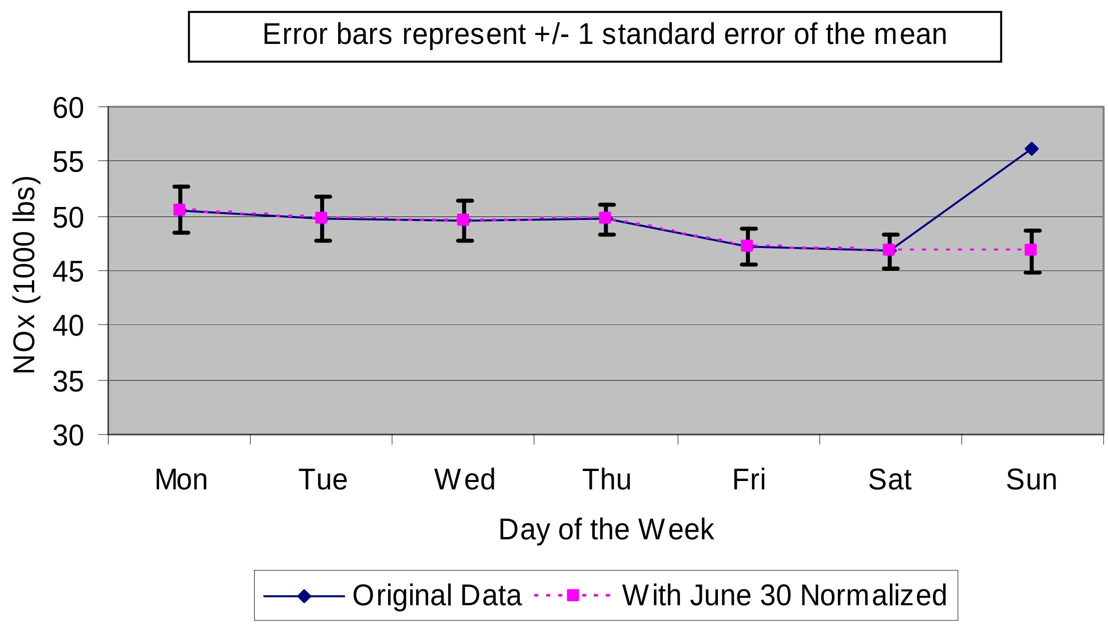


Figure 4-2. Average NO_x emissions for major point sources in the SoCAB, as reported through CEMS for June 2002 through August 2002.

Lastly, we normalized the emissions for every facility according to the relative magnitude of emissions for each facility. This normalization scheme equally weights each facility, regardless of the scale of individual facilities' emissions. The results demonstrated that on average, facilities' emissions on Saturdays and Sundays are 10% lower than they are on weekdays (**Figure 4-3**). Because the average WD-WE reduction in the average facility-normalized emissions is somewhat larger than the corresponding reduction in average total emissions (10% > 6%), we concluded that smaller facilities tend to experience larger WD-WE reductions in emissions than do larger facilities. The summary of results shown in **Table 4-1** confirms this conclusion.

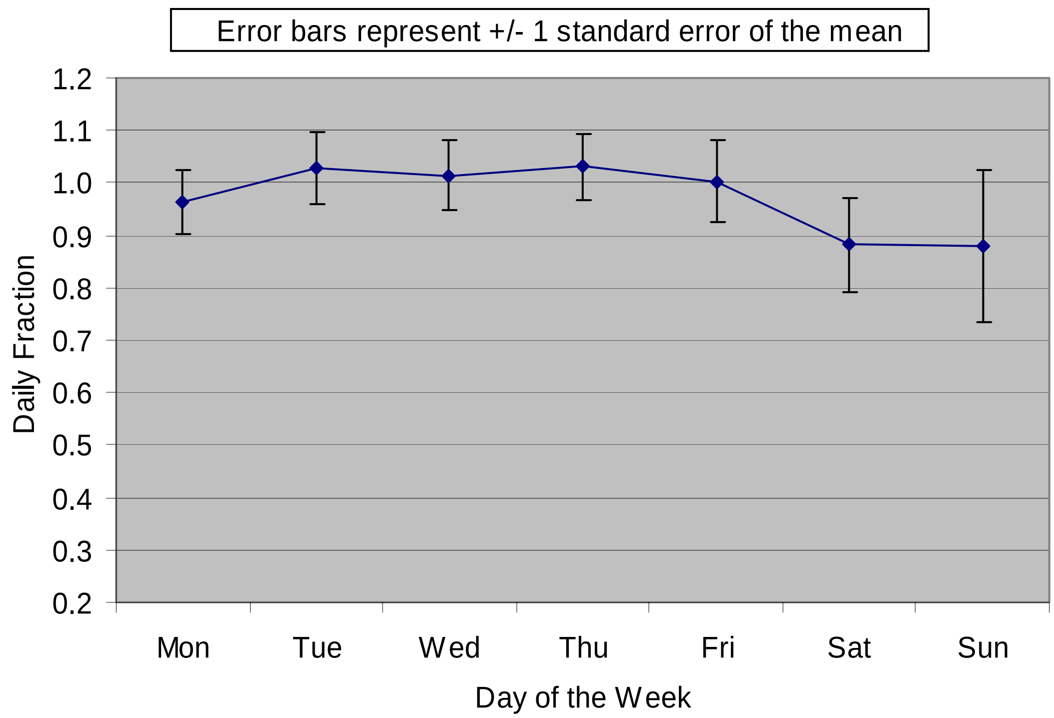


Figure 4-3. Normalized NO_x emissions for major point sources in the SoCAB, as reported during the summer of 2002 through the continuous emissions monitoring system (CEMS).

Table 4-1. Weekday vs. weekend NO_x emission reductions by facility size.

Time of Week	NO_x Emissions (1000 lbs)		
	Largest 20 Emissions Sources	Smaller 58 Emissions Sources	Total
Average WD (Mon-Thu)	40.23	9.67	49.90
Average Friday	37.92	9.26	47.18
Average WE (Sat-Sun)	38.17	8.58	46.75
% Decrease WD to WE	5.11%	11.25%	6.30%

4.3 SUMMARY OF FINDINGS FOR POINT SOURCES

In summary, CEMS data acquired for summer 2002 suggest that major point sources follow WD-WE emissions patterns, as do mobile and area sources. The following conclusions were drawn:

- Total NO_x emissions from point sources typically declined approximately 6% on Friday through Sunday relative to total emissions on Monday through Thursday.

- Low-emitting facilities tended to experience larger WD-WE swings in emissions (10%, on average) than did the highest-emitting facilities, which experienced WD-WE emissions reductions of only 4%, on average.
- Emissions from high-emitting facilities declined on Friday through Sunday, while emissions from low-emitting declined only on Saturday and Sunday.

5. SUMMARY AND RECOMMENDATIONS

This study demonstrates that significant weekday-to-weekend variability occurs throughout the major components of the emission inventory: on-road mobile sources, off-road mobile sources, area sources, and point sources. Much of this variability can now be quantified for the SoCAB and applied to generate more accurate emission inventories and air quality modeling results for weekends. In addition, several areas of further research can be identified that would allow more improvements and refinements to weekend emission inventories for the SoCAB.

Key findings of this study are that activity levels for on-road mobile sources, commercial off-road mobiles sources, and commercial area sources decline on weekends relative to weekdays. In addition, NO_x emissions from point sources were observed to decline on weekends. In contrast, activity levels for recreational off-road mobile sources and recreational area sources increase on weekends relative to weekdays. Common sense would indicate that these shifts, and shifts in the diurnal patterns for on-road mobile sources and recreational sources, are clearly due to variations in peoples' behavior as they follow their work-week and weekend habits. Some unexpected findings that are also likely to be related to work-week and weekend habits are (1) substantial accrual of VMT at vehicle speeds above 65 miles per hour, especially on weekends, (2) predominance of travel on major highways, especially on weekends, (3) possible preferential selection of light-duty utility vehicles over passenger vehicles for weekend travel, and (4) shifts in activities from central urban locations towards outlying and recreational areas on weekends.

Based on these key findings, we recommend the following specific adjustments to the weekday emission inventory for the SoCAB, which will facilitate the development of weekend emission inventories:

- Slightly increase light-duty vehicle VMT by approximately 3.5% on Fridays. Reduce light-duty vehicle VMT by approximately 10%-20% on Saturdays and approximately 30% on Sundays.
- Increase the number of light-duty vehicle soaks by approximately 10% on Fridays. Reduce the number of light-duty vehicle soaks by approximately 20% on Saturdays and 30% on Sundays.
- Reduce heavy-duty vehicle activity by approximately 55%-70% on Saturdays and approximately 75%-80% on Sundays.
- Adjust the diurnal profile for light-duty vehicles to reflect a single-mode pattern on weekends and to slightly increase the proportion of VMT that occurs during Friday late afternoons and evenings.
- Adjust speed distribution profiles to reflect greater proportions of VMT occurring at high speeds on weekends.
- Significantly increase activity levels and emissions for sources associated with recreational activities on weekends. These sources include recreational boats,

recreational off-road vehicles, and barbecues. Our results indicate that source-specific increases on the order of 25% to 165% may be reasonable.

- Apply diurnal profiles to recreational emissions sources that reflect their tendency to occur in the afternoons.
- Significantly reduce activity levels and emissions for sources associated with business activities on weekends. Examples of these sources include commercial lawn and garden equipment and construction equipment. Our results indicate that decreases on the order of 60% to 99% may be reasonable.
- Apply day-specific emissions data for NO_x from point sources, which were approximately 6% lower on weekends than on weekdays.

In addition, we propose the following specific recommendations for further research:

- Develop emissions models that better reflect travel activities at high speeds above 65 miles per hour.
- Investigate whether the modeled number of starts and/or soaks per day should be reduced.
- Investigate further the extent to which emissions should be spatially re-allocated toward recreational areas on the weekends.
- Investigate further whether light-duty utility vehicles have slightly higher activity levels on weekends than on weekdays, which offset slightly lower activity levels for passenger vehicles.
- Further investigate and analyze the data and results that have been collected through this study. (Data files are provided in Appendix F.)

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7. GLOSSARY OF TERMS AND ABBREVIATIONS

ARB	California Air Resources Board
AF	allocation factors
Arterial Street	An arterial is a roadway that serves major traffic movements and secondarily provides access to abutting land (Harvey and Deakin, 1993).
Business Activity	Activities related to business functions, which are assumed to be directly related to emission rates from business-associated emissions sources such as internal combustion engines, miscellaneous solvents, and others. For the purposes of this report, business activities were measured in units of labor-hours worked by business employees.
Caltrans	California Department of Transportation
CAMP	Caltrans/ARB Modeling Program
CEMS	Continuous Emission Monitoring Systems
Collector Street	A collector is an urban street that channels traffic from local streets to minor and major arterials and secondarily provides access to residential neighborhoods, commercial, and industrial districts (Harvey and Deakin, 1993).
GIS	geographic information systems
GPS	global positioning system
Heavy-duty truck	For the purposes of WIM traffic volumes, heavy-duty trucks included vehicles with four or more axles. For the purposes of surface street traffic counters, heavy-duty trucks included the following: • Double-Unit Trucks with 6 or 7 Axles • Multi-Unit Truck with 4 or 5 Axles • Multi-Unit Truck with 6 Axles • Multi-Unit Truck with 7+ Axles
HDV	heavy-duty vehicle (see heavy-duty truck)
IC	internal combustion
Local Street	A local street provides access within residential neighborhoods, commercial, and industrial districts (Harvey and Deakin, 1993).
Light-duty Utility Vehicle	For the purposes of the GeoLogger study, light-duty utility vehicles included pickups, vans, and sport-utility vehicles. For the purposes of the WIM traffic volumes and surface street traffic counters, light-duty utility vehicles were counted as part of the passenger vehicle fleet.

Medium-Duty Truck	For the purposes of the surface street traffic counters, medium-duty trucks included the following: • Single Unit Truck with 2 Axles, 6 Tires • Single Unit Truck with 3 Axles • Single Unit Truck with 4 Axles For the purposes of the WIM traffic volumes, these vehicles were distributed to the heavy-duty truck and passenger vehicle fleets according to the number of axles.
N	number of postcards received
NO_x	oxides of nitrogen
Passenger Vehicle	For the purposes of WIM traffic volumes, passenger vehicles were defined as vehicles with two or three axles. For the purposes of surface street traffic counters, passenger vehicles included motorcycles, passenger cars, pickups, sport-utility vehicles, and vans. For the purposes of the GeoLogger study, passenger vehicles included passenger cars only, while pickups, vans, and sport-utility vehicles were considered separately as light-duty utility vehicles.
PRR	positive response rates
Recreational Activity	Activities related to recreational functions, which are assumed to be directly related to emission rates from residence-associated emissions sources such as recreational boats, recreational car trips, and others. For the purposes of this report, recreational activities were measured according to the frequencies of reported occurrences; and recreational driving patterns were hypothesized to occur in the vicinities of or corridors to recreational attractions.
Residential Activity	Activities related to residential functions, which are assumed to be directly related to emission rates from residence-associated emissions sources such as internal combustion engines, miscellaneous solvents, and others. For the purposes of this report, residential activities were measured according to the frequencies of reported occurrences.
ROG	reactive organic gas
SCAG	South Coast Association of Governments
SCAQMD	South Coast Air Quality Management District
SCFS	speed correction factors
SoCAB	South Coast Air Basin
VMT	vehicle miles of travel
VOCs	volatile organic compounds
WD-WE	weekday-weekend
WIM	weigh-in-motion

APPENDIX A

GROUND TRUTH SURVEYS

(CHARACTERIZATION OF POTENTIAL EMISSION SOURCES AROUND SELECTED AMBIENT AIR QUALITY MONITORING SITES)

The purposes of performing the ground-truth surveys were to (1) qualitatively verify through human observation WD-WE patterns of traffic and other human activities, which are presented and discussed in the main body of this report, and (2) assess the potential for bias in air quality measurements due to unusual or strong emissions sources in the near vicinities of air quality monitoring sites. As described in this appendix, WD-WE patterns were observed to be qualitatively consistent with the quantitative observations presented in this report. In addition, no unusual or strong emissions sources were observed; therefore, no potential sources of bias in air quality measurements were identified.

AZUSA MONITORING SITE

Figure A-1 displays points of interest around the Azusa monitoring site.

- The sampler is located at the corner of Todd Ave. and 10th Street.
- Interstate 210 runs through areas observed around the sampling site.
- The San Gabriel River runs through the northwest end of the observed area.
- Running east/west is the major surface street Foothill Blvd.
- The Santa Fe Dam Recreational Area takes up a large portion of the southwest end of the sampling area. Gravel pits flank the dam.
- Azusa Greens Country Club is northeast of the sampler. More gravel pits are on the West Side of the golf course.
- Railroad tracks run through the sample area.
- There is a dense residential area just east of the sample site and across the river in the northwest direction.

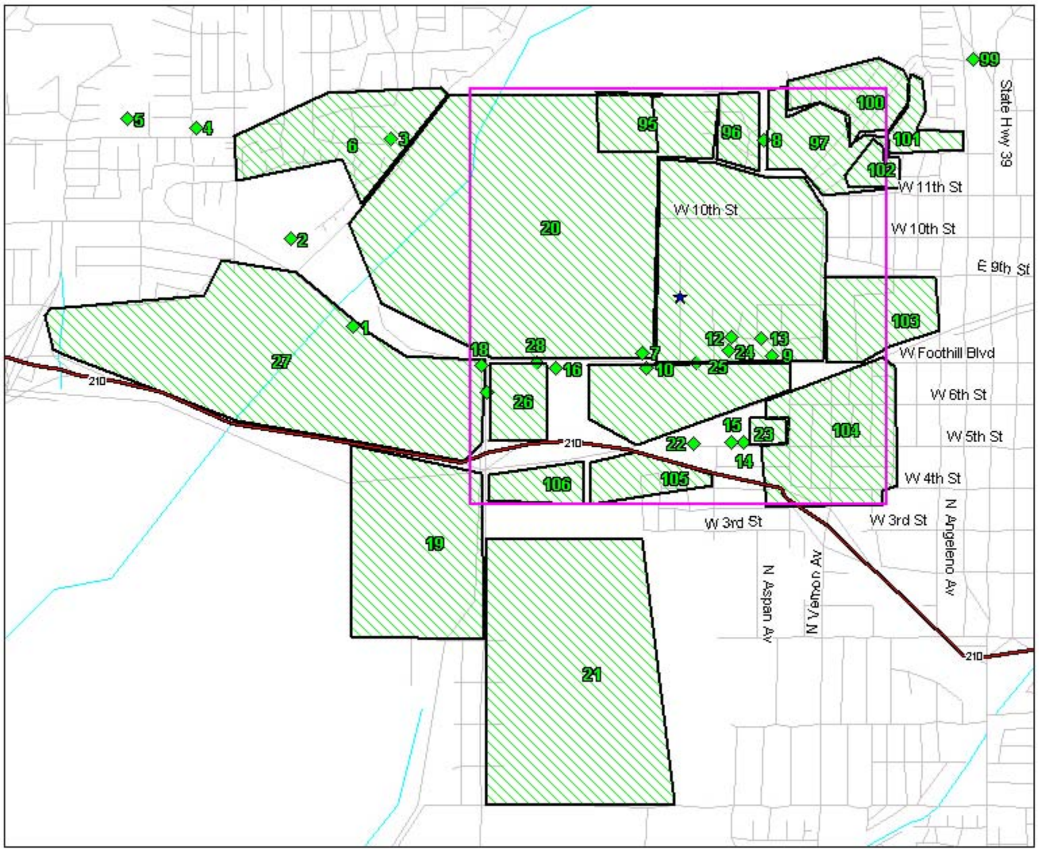

Figure A-1. Azusa monitoring site. (Star denotes the location of the monitoring site; diamonds and hatched areas are points of interest.)

Observations for Thursday, July 25, 2002

6:00 a.m. – 8:30 a.m.
Driving observation began at the corner of Foothill Blvd. and Todd Ave. A few joggers and an increase in traffic of diesel trucks along Foothill Blvd. were observed. An increase in the number of trucks going to and leaving from the construction site at Todd Ave. and Sierra Madre Ave. was observed (95). The number of joggers increased in the hours of 7:00 a.m. and 8:00 a.m.

8:30 a.m. – 10:00 a.m.
A small amount of golf carts were observed on Sierra Madre Ave. The auto traffic lessened and the amount of trucks going to and leaving from the construction site decreased. There was an increase in the number of people washing their cars. The City bus ran every 10 minutes.

After 10:00 a.m. dump trucks traveling on Foothill Blvd. and Vernon were observed.

Observations for Sunday, July 28, 2002, compared to Thursday, July 25, 2002

- 6:00 a.m. to 7:00 a.m. time period: fewer autos and fewer trucks
- 7:00 a.m. to 8:00 a.m. time period: less auto traffic, a few golf carts driving on Sierra Madre Ave. Around 7:25 a.m. a single car fatal accident closed Todd Ave. and 10th St.
- 8:00 a.m. to 9:00 a.m. time period: more people washing cars, jogging, and watering lawns, city buses less frequent. A convoy of old model cars passed the site
- 9:00 a.m. to 10:00 a.m. time period: less truck traffic, more bike riders, city buses running less frequent, and more golf carts observed. Roads from accident reopened

Azusa Points and Areas of Interest

1. Public Institution; Lario San Gabriel River Trail; Other; horse and bike trail;
2. Construction; senior residence; appt building for seniors;
3. Public Institution; Duarte Historical Museum; Museum with small park;
4. Public Institution; Royal Oaks Park; park with small playground and tennis courts;
5. Public Institution; Royal Oaks Elementary school;
6. Residential Zone; area northwest of site;
7. Refueling; Texaco; fuel and auto repair; on the corner of Foothill Blvd. and Todd;
8. Public Institution; Azusa Greens Country Club; golf course;
9. Residential Zone; mix of apartments and single-family homes;
10. Food Preparation; Carl's Jr.; fast food; there is a Taco Bell to the east of this Carl's Jr.;
12. Vehicle; Laidlaw Bus Co.; school bus yard;
13. Industry; Galleher Lumber Co.; lumber;
14. Industry; Tru Wood Products; lumber
15. Industry; Carter's; Metal; Fabrication;
16. Misc. Business; Homegrocer.com; food distribution center; many trucks;
17. Food Preparation; McDonalds; fast food;
18. Refueling; Arco; retail re-fueling;
19. Industry; Miller Brewing; brewery;
20. Industry; Vulcan Materials; Reliance Quarry;

21. Industry; Gen Corp Aerojet; Aerospace company;
22. Industry; Wynn; production of oil additives for products like STP;
23. Construction; building construction; large industrial park under construction;
24. Food Preparation; El Toro Bravo #4; mexican food;
25. Commercial Zone; light industrial park; no major sources of pollution were noted;
26. Commercial Zone; Foothill Business Park; business park;
27. Industry; Vulcan Landfill; class \U\ landfill;
28. Commercial Zone; health valley; warehouse;
29. Misc. Business; Tim's Auto Center; auto service; on the corner of Foothill Blvd. and Georgia Ave;
30. Food Preparation; Corky's Coffee House; small diner; serves breakfast and lunch only;
95. Construction; business under construction; located at the extreme eastern edge of the quarry at the corner of Todd and W. Sierra Madre Ave;
96. Residential Zone; residential; semi-large duplex-type apartment community;
97. Public Institution; Azusa Greens Golf Course; golf course playing area;
99. Residential Zone; residential;
100. Park; Henry A. Williams Northside Park; medium-sized community park;
101. Public Institution; Hodge Elementary School; elementary school;
102. Residential Zone; mix of single-family homes and apartments; most of the homes have chimneys;
103. Industry; industrial park; industrial area including a lumber mill and a metal pipe storage area; both metal and pulp/paper/wood; both processing and storage/transport types and subtypes;
104. Residential Zone; small single-family homes;
105. Industry; Norththrop Aerospace;
106. Industry; industrial park; consists of small industrial businesses;
107. Food Preparation; Best Teriyaki; fast food restaurant;

BURBANK MONITORING SITE

Figure A-2 displays points of interest around the Burbank monitoring site.

- Interstate 5 runs southeast/northwest in the upper northeast of the monitoring location.
- George Izay Park is located to the southwest of the monitoring location.
- Griffith Park is located to the south of the monitoring location.
- The Media City Center complex is located to the northeast on the opposite side on the Interstate.
- Railroad tracks parallel Interstate 5 northeast of the site.
- Four major streets encompass the monitoring site: N. Lake St., W. Olive Ave., N. Victory Blvd., and W. Magnolia Blvd.

Figure A-2. Burbank monitoring site. (Star denotes the location of the monitoring site; diamonds and hatched areas are points of interest.)

Observations for Wednesday, August 14, 2002

6:00 a.m. –7:00 a.m.
Moderate auto traffic on Interstate 5. One city metro train (118) passed along the railroad tracks south of the Interstate and city buses passed by every 10-15 minutes. 5-10 trucks were at the construction site located at First St. and Magnolia Ave. On Lake St. and Palm Ave. forklift trucks passed the site in the 7:00 a.m. hour. A few joggers and walkers were observed between 7:00 a.m. and 8:00 a.m.

8:00 a.m. – 9:00 a.m.
Another metro train passed the site (118) and the city buses continued to run about every 15-20 minutes. Moderate auto traffic and light truck traffic continued on Interstate 5. Smoke and steam were observed from a smokestack at the public works center (119).

After 9:00 a.m. heavy auto traffic and light foot traffic were observed. The city buses continued to run every 5-15 minutes.

Observations for Sunday, August 25, 2002, compared to the Wednesday, August 14, 2002

- 6:00 a.m. to 7:00 a.m. time period: fewer autos and trucks, fewer city buses, and no school buses in operation
- 7:00 a.m. to 8:00 a.m. time period: more people watering lawns, more bicycles, smoke rising from stack at public works building
- 9:00 a.m. to 10:00 a.m. time period: fewer autos

Burbank Points and Areas of Interest

108. Public Institution; Walt Disney School; elementary school; on the corner of Mariposa and Orange Grove Ave.;
109. Public Institution; Burbank Little Theatre; park, museum and theatre;
110. Food Preparation; Genios; Italian sit-down restaurant; on the corner of Olive and Beechwood;
111. Food Preparation; Mc Donald's; fast food; on the corner of Olive and Reese Pl.;
112. Misc. Business; Safari Inn; motel; corner of Parish and Olive;
113. Public Institution; Burroughs High School;
114. Misc. Business; In & Out Paint and Body; Auto paint and body shop; on the corner of Victory and Verdugo;
115. Misc. Business; little section of many auto body shops; on Victory Blvd. between Verdugo and Providencia;
116. Industry; Burbank Recycle Center; paper recycling center; on Flower St. near Interstate 5;
117. Industry; Bormann Steel; fabrication of steel products;
118. Vehicle; Burbank Metro link station; commuter train station;
119. Industry; Burbank Water & Power; water and power plant;
120. Refueling; Texaco; lumber sales and storage;
121. Refueling; Texaco; retail gas sales; on the corner of Magnolia and Victory;

122. Commercial Zone; Costco wholesale; large warehouse store including auto maintenance and retail gas;
123. Food Preparation; The Place For Steaks; steak restaurant; on the corner of Burbank and Mariposa;
124. Public Institution; Burbank High School; high school;
125. Commercial Zone; Burbank Entertainment Village; large area for shopping and dining; many restaurants and retail stores;
126. Residential Zone; mix of single-family homes and apartments; homes and civic center also in this area;
127. Residential Zone; single-family homes;
128. Residential Zone; mixed area of homes and small businesses;
129. Residential Zone; mix of single-family homes and apartment buildings
130. Misc. Business; Bindary Co.; magazine bindary business;
131. Misc. Business; Firing Range; indoor shooting range;
132. Misc. Business; Burbank Animal Shelter;
133. Commercial Zone; small; mixed area; abandoned Big 5 Sporting Goods store, small animal shelter, aluminum storage units, three single-family homes;

LA N. MAIN ST. MONITORING SITE

Figure A-3 displays points of interest around the LA N. Main St. monitoring site.

- The Los Angeles River runs north/south to the east of the sampling site.
- Amtrak line follows along the river and circles the sampling site.
- Just north of the monitoring site is the Elysian Park recreational area.
- Dodger Stadium is located just south of the park, northwest of the site.
- I-5 runs north/south.
- Highway 101 runs west/east.
- Interstate 110 runs southwest/northwest.
- North Main Street is a major surface arterial running past the monitoring site.
- Southwest area is a dense mixed area of homes and restaurants.
- South of the site is the Los Angeles County Central Jail.

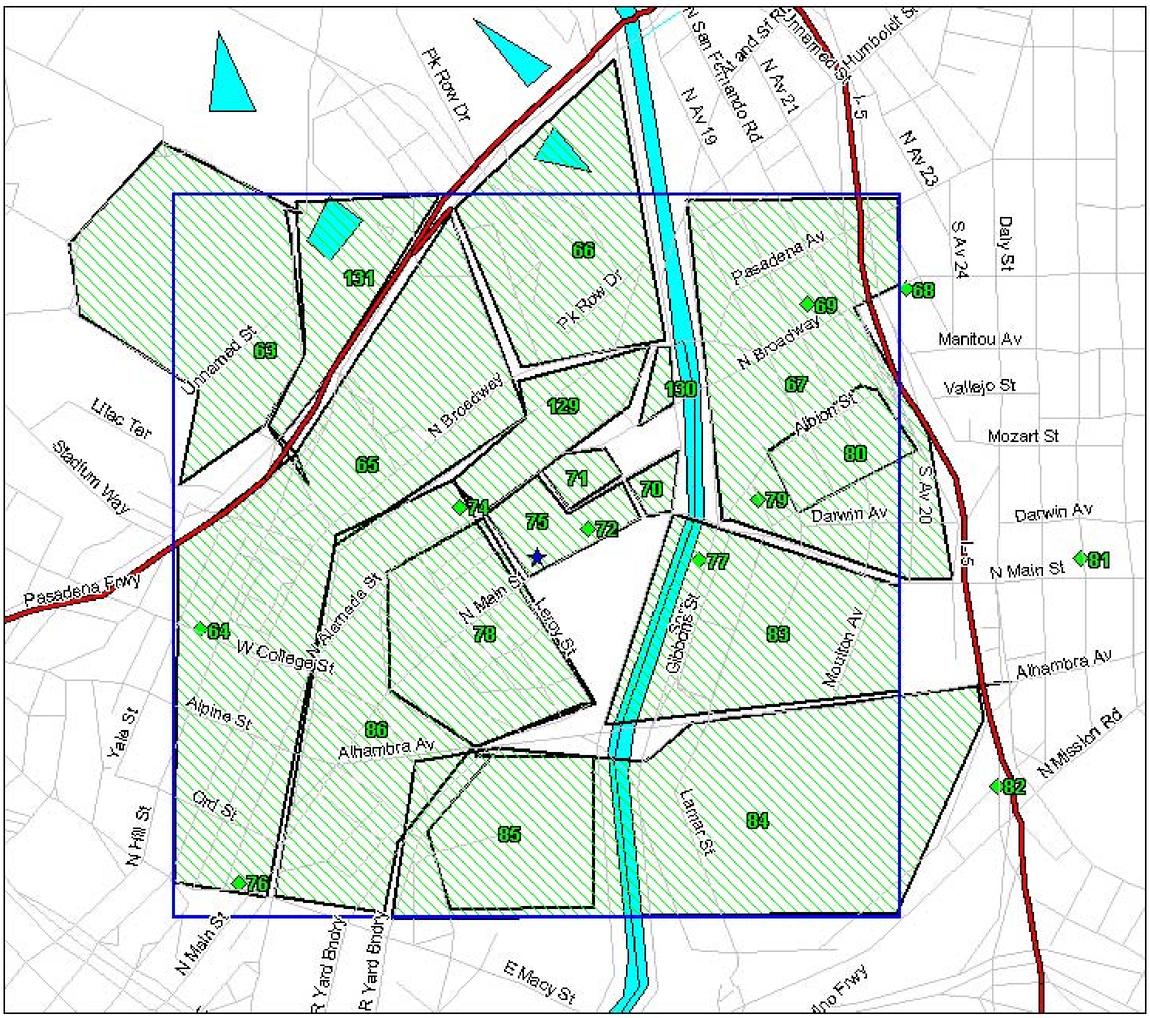

Figure A-3. LA N. Main St. monitoring site. (Star denotes the location of the monitoring site; diamonds and hatched areas are points of interest.)

Observations for Wednesday, July 31, 2002

6:00 a.m. –8:00 a.m.
There is light traffic on Interstate 5 and N. Main St. 10-15 trucks passed near the site along with four school buses. The city bus route has buses operating every 10 minutes. Moderate auto traffic and 15-25 trucks passed the site between 7:00 a.m. and 8:00 a.m.. Another 5-10 school buses also passed the site in the 7:00 a.m. hour along with a few joggers.

8:00 a.m.–9:00 a.m.
Auto traffic increased on surrounding surface streets. There were many people walking on streets in the areas surrounding the site. A fire occurred on the hillside above Interstate 110 and Stadium Way. 1-15 trucks passed the site during the 8:00 a.m. hour along with a few joggers.

After 9 a.m. heavy traffic continued on N. Main St, and N. Board Way. Food vendors were observed on N. Spring St .and E. Cesar Chavez Ave. The city buses passed every 10-15 minutes along with a few joggers.

Observations for Sunday, August 4, 2002, compared to Wednesday, July 31, 2002

- 6:00 a.m. to 8:00 a.m. time period: fewer autos, no school buses in use, less truck traffic, more walkers and joggers
- 8:00 a.m. to 9:00 a.m. time period: fewer autos, more food and street vendors out, more people outside churches, walking and jogging
- 9:00 a.m. to 10:00 a.m. time period: less auto traffic, street vendors, and city buses running every 10-15 minutes

LA N. Main Points and Areas of Interest

134. Public Institution; Dodger Stadium; baseball stadium;
135. Refueling; 76 gas station; retail re-fueling;
136. Other; Chinatown; ethnic community area; area consisting of mixture of homes, apartments, small businesses, many restaurants;
137. Public Institution; Elysian Park; park; small portion of park in mapped area;
138. Residential Zone; mixed area; mixture of residential, small business and light industry;
139. Refueling; Thrifty Gas; retail re-fueling;
140. Refueling; 76 gas; retail re-fueling;
141. Industry; none; area of warehouses for seafood;
142. Industry; Stadco Fab Ship;
143. Industry; West America
144. Vehicle; Atlanta Express; school bus parking lot and service garage;
145. Industry; Mckenna Boiler Works;
146. Industry; DWP Main center;
147. Refueling; 76 gas; retail re-fueling;
148. Industry; Transit Mixed Concrete;
149. Residential Zone; low income housing project;
150. Industry; Atlas Carpet Mills; carpet fabrication;
151. Residential Zone:

152. Refueling; C&J Gas; retail re-fueling;
153. Refueling; Chevron; retail re-fueling;
154. Industry; mixed area; mixture of warehouses and light industry;
155. Vehicle; Amtrak train; this whole area is passenger terminal plus cargo train loading and unloading warehouse facility;
156. Public Institution; Los Angeles County Jail;
157. Other; mixed area; mixture of light industry, warehouses, fast food restaurants, auto repair shops and residential;
158. Construction; Metro Link; facility for metrolink train;
159. Commercial Zone; area consisting of small warehouses;
160. Farm; hilly area; hilly area near a water reservoir;

LYNWOOD MONITORING SITE

Figure A-4 displays points of interest around the Lynwood monitoring site.

- To the south of the monitoring site is Interstate 105, running east/west.
- Lynwood Park is east of the monitoring location.
- Directly to the north of Lynwood Park is St. Francis Medical Center.
- Interstate 710 runs north/south to the east of the sampling area.
- Directly to the north of the monitoring location is the E Imperial Highway, which runs east/west.

Figure A-4. Lynwood monitoring site. (Star denotes the location of the monitoring site; diamonds and hatched areas are points of interest.)

Observations for Wednesday, August 7, 2002

6:00 a.m. – 8:00 a.m.
There was heavy auto traffic in the westbound lane of the 105 Freeway, along with moderate truck traffic. The Metro train ran about every 20-25 minutes and the city buses ran every 10-15 minutes. There was moderate foot traffic around the bus station on Long Beach Blvd. Two to three people were watering their lawns and one person mowed their lawn.

8:00 a.m. – 9:00 a.m.
Heavy auto traffic occurred at the intersection of Martin Luther King Blvd. and Imperial Highway near the hospital (157). The city buses ran about every 5-10 minutes.

After 9:00 a.m. heavy traffic was observed on Long Beach Blvd. and Imperial Highway. Heavy traffic continued in the westbound direction on the 105 Freeway while traffic in the eastbound lanes remained light.

Observations for Sunday, August 11, 2002, compared to Wednesday, August 7, 2002

- 6:00 a.m. to 8:00 a.m. time period: fewer autos, city buses less frequent
- 8:00 a.m. to 9:00 a.m. time period: more pedestrians, more people washing cars, more people watering lawns, fewer autos
- 9:00 a.m. to 10:00 a.m. time period: fewer autos

Lynwood Points and Areas of Interest

161. Public Institution; St. Francis; Hospital;
162. Public Institution; Lynwood Civic Center; Civic Center; City Hall, Police Dept. and Library;
163. Park; Lynwood Park;
164. Public Institution; Hosler Middle School; school;
165. Residential Zone; mix of single-family homes and a few apartment buildings;
166. Public Institution; Woodrow Wilson;
167. Residential Zone;
168. Food Preparation; Acosta's; Food; on the southwest corner of Long Beach Blvd. and Louise'
169. Refueling; USA Gas;
170. Commercial Zone; shopping center;
171. Residential Zone;
172. Misc. Business; Bestways; distribution center;
173. Industry; Martin Metal Finishing; metal fabrication;
174. Food Preparation; Hercules Burgers; fast food; on the corner of Imperial Highway and Fernwood;
175. Residential Zone;
176. Industry; apparent abandoned storage facility;
177. Food Preparation; Taqueria 4 Amigos; Mexican food;
178. Food Preparation; Lucy's; Mexican food; open 24 hours a day;

179. Refueling; Sun’s; mini mart and gas station on the southeast corner of Long Beach Blvd. and Martin Luther King Blvd.;
180. Refueling; J&S 76 Gas; open 24 hours a day; on the northeast corner of California and Martin Luther King Blvd;
181. Food Preparation; Tom's #5; fast food;
182. Residential Zone; mix of single family homes and apartment buildings;
183. Commercial Zone; Lynwood Plaza; shopping center;
184. Residential Zone; apartment buildings

RUBIDOUX MONITORING SITE

Figure A-5 displays points of interest around the Rubidoux monitoring site.

- Interstate 60 runs east/west to the north of the monitoring location.
- To the south of the monitoring location is Jensen-Alvarado Historic Ranch Park.
- Further south beyond the park is Flabob Airport.
- Just north of Interstate 60 rail tracks run in the east/west direction.
- To the east of the sampling area, across the river is the Fairmount Municipal Golf Course.

Figure A-5. Rubidoux monitoring site. (Star denotes the location of the monitoring site; diamonds and hatched areas are points of interest.)

Observations for Wednesday, August 21, 2002,

6:00 a.m. – 8:00 a.m.
Moderate traffic on Highway 60 was observed. There were about 40-50 cars waiting to get into the swap meet at the local drive-in (148). There were also 10-15 cars waiting in line to get into a recycle center. City buses ran about every 20-25 minutes.

8:00 a.m. – 10:00 a.m.
Light car traffic and moderate truck traffic was observed in the surrounding area. City buses continued to run every 20-25 minutes. There was light foot traffic around the swap meat. Heavy auto traffic in and around the shopping center (135) on the corner of Mission Blvd. and Limonite Ave. was observed.

Observations for Sunday, August 25, 2002, compared to Wednesday, August 21, 2002

- 6:00 a.m. to 7:00 a.m. time period: fewer autos on Highway 60, more cars at the swap meet location
- 7:00 a.m. to 8:00 a.m. time period: more foot traffic. Fewer trucks, more joggers, more people washing cars, more people watering lawns
- 9:00 a.m. to 10:30 a.m. time period: 10-15 people riding off-road vehicles off of Highway 60 and Pacific Ave.

Rubidoux Site Points and Areas of Interest

185. Misc. Business; The Tire Shoppe; next to monitor site;
186. Residential Zone;
187. Food Preparation; Tastee Freeze; fast food; all outdoor seats; on the corner of Avalon and Mission;
188. Commercial Zone; Mission Plaza; small strip mall;
189. Public Institution; West Riverside School; elementary school;
190. Residential Zone; mix of single-family homes and apartments;
191. Refueling; 76 gas; mini-mart and gas station; on the southwest corner of Mission and Riverview;
192. Misc. Business; Auto Zone; auto parts store; on the northeast corner of Mission and Riverview;
193. Food Preparation; China Wok; Chinese restaurant;
194. Public Institution; Jensen-Alardo Ranch; historic ranch and museum;
195. Residential Zone; area surrounding the historic ranch and museum;
196. Public Institution; Cornerstone Church; church; on the corner of Pacific and Limonite;
197. Residential Zone;
198. Public Institution; Ruboidux High School;
199. Refueling; Ultramar; mini mart and gas station; on the southwest corner of Mission and Opal;
200. Refueling; 76 gas; southeast corner of mission and Opal
201. Misc. Business; Ruboidux Drive In; drive-in theatre;
202. Residential Zone; residential; area around drive-in theatre;
203. Farm; dirt fields;

204. Residential Zone;
205. Farm; dirt fields;
206. Public Institution; Mission Middle School; backed up against freeway at La Rue St.;
207. Farm; Dirt Field; across from Mission Middle School and extends out to Mission blvd.;
208. Residential Zone; area near monitor site;
209. Public Institution; Eddie Smith Senior Community; Senior Center; senior community center and apartment complex adjoining monitor site